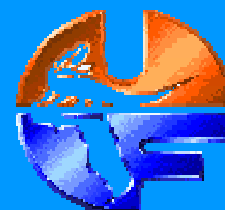


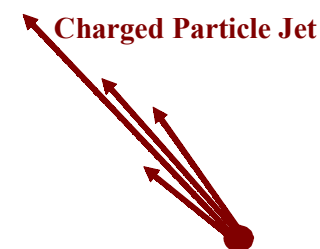


The “Underlying Event” in Run 2 at CDF

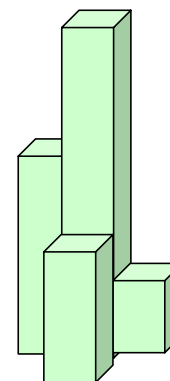


Outline of Talk

- ➔ Study the “underlying event” as defined by the leading “charged particle jet” and compare with the Run I analysis.
- ➔ Study the “underlying event” as defined by the leading “calorimeter jet” and compare with the “charged particle jet” analysis.
- ➔ Study the relationship between “charged particle jets” and “calorimeter jets”.



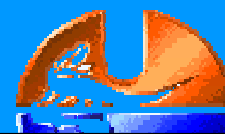
Calorimeter Jet



JetClu $R = 0.7$



The “Underlying Event” in Run 2 at CD



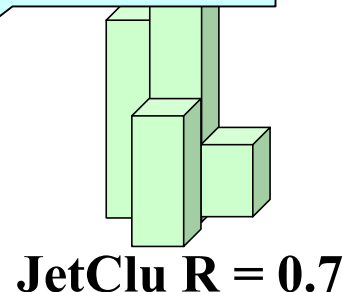
Outline of Talk

- ➔ Study the “**underlying event**” as defined by the leading “**charged particle jet**” and compare with the Run I analysis.
- ➔ Study the “**underlying event**” as defined by the leading “**calorimeter jet**” and compare with the “**charged particle jet**” analysis.
- ➔ Study the relationship between “**charged particle jets**” and “**calorimeter jets**”.

Look at charged particle correlations relative to the leading “**charged particle jet**”.

Look at charged particle correlations relative to the leading “**calorimeter jet**”.

Look at correlations between the leading “**charged particle jet**” and “**calorimeter jets**”.





The “Underlying Event” in Run 2 at CD



Outline of Task

➔ Study the “underlying event” as defined by the leading “charged particle jet” and compare with the “calorimeter jet”.

➔ Study the “underlying event” by the leading “charged particle jet” and compare with the “calorimeter jet” analysis.

➔ Study the relationship between “charged particle jets” and “calorimeter jets”

Look at charged particle correlations relative to the leading “charged particle jet”.

Look at charged particle correlations relative to the leading “calorimeter jet”.

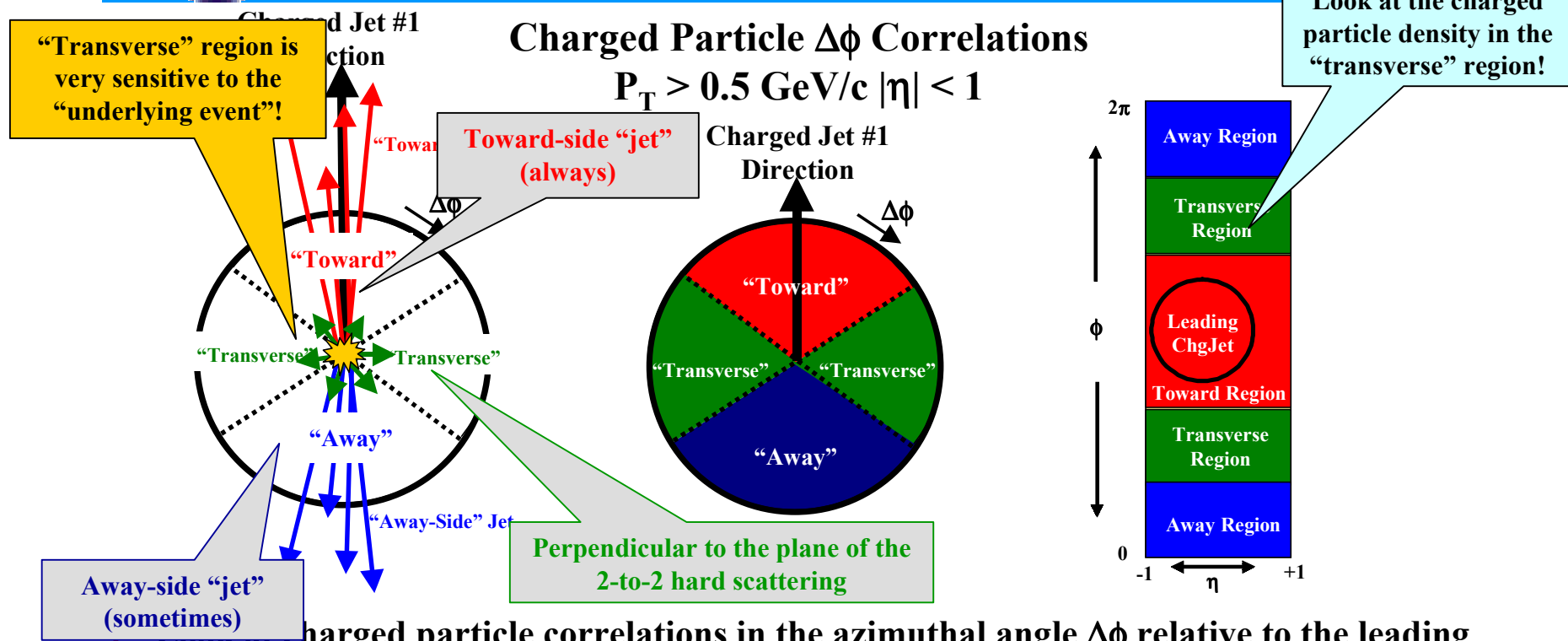
Compare the data with **PYTHIA Tune A** which was tuned to fit the Run 1 “underlying event”.

Look at correlations between leading “charged particle jets” and “calorimeter jets”.

Extrapolate to the LHC! = 0.7



“Underlying Event” as defined by “Charged particle Jets”

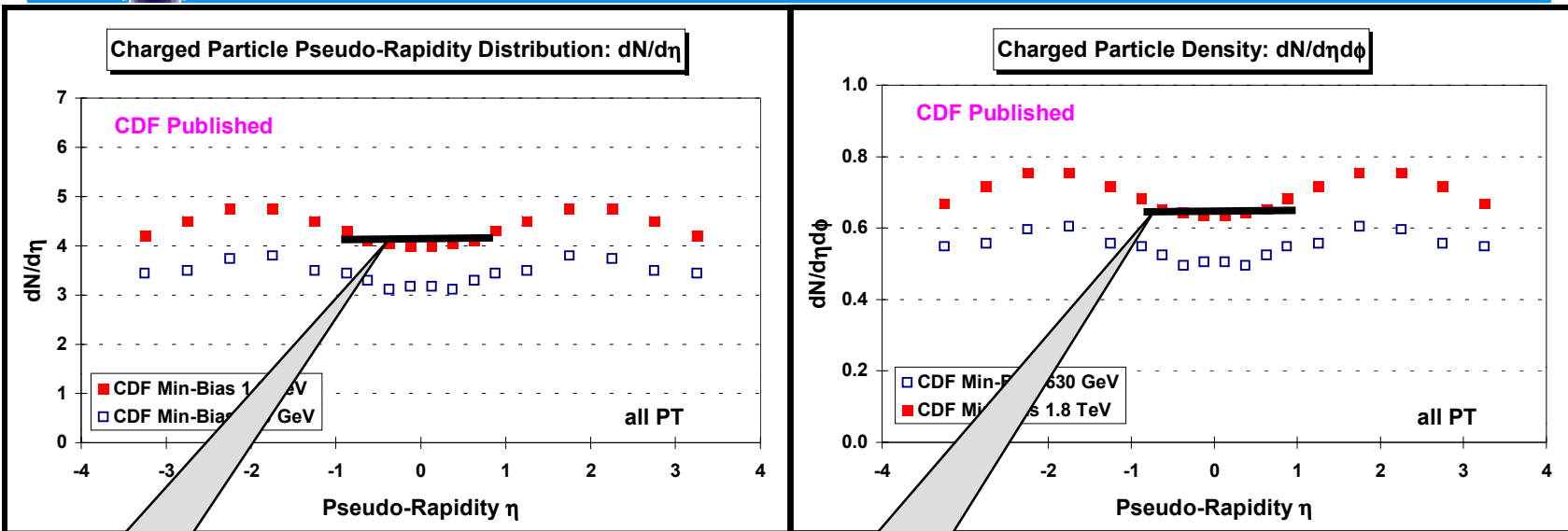


Look at charged particle correlations in the azimuthal angle $\Delta\phi$ relative to the leading charged particle jet.

- ➔ Define $|\Delta\phi| < 60^\circ$ as “Toward”, $60^\circ < |\Delta\phi| < 120^\circ$ as “Transverse”, and $|\Delta\phi| > 120^\circ$ as “Away”.
- ➔ All three regions have the same size in η - ϕ space, $\Delta\eta \times \Delta\phi = 2 \times 120^\circ = 4\pi/3$.



CDF Run 1 “Min-Bias” Data Charged Particle Density



$$\langle dN_{\text{chg}}/d\eta \rangle = 4.2$$

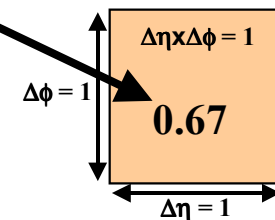
“Min-Bias” data on the

$$\langle dN_{\text{chg}}/d\eta d\phi \rangle = 0.67$$

particles per unit pseudo-rapidity

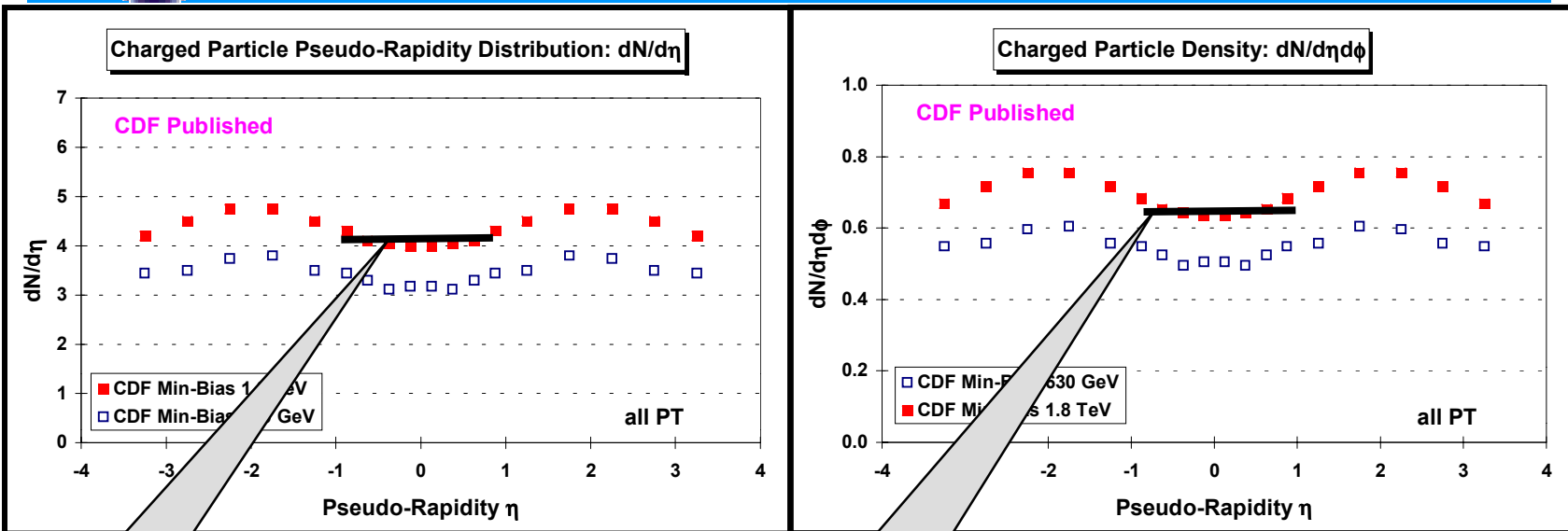
at 630 and 1,800 GeV. There are about **4.2 charged particles per unit η in “Min-Bias” collisions at 1.8 TeV ($|\eta| < 1$, all P_T).**

- ➔ Convert to charged particle density, $dN_{\text{chg}}/d\eta d\phi$, by dividing by 2π . There are about **0.67 charged particles per unit η - ϕ in “Min-Bias” collisions at 1.8 TeV ($|\eta| < 1$, all P_T).**





CDF Run 1 “Min-Bias” Data Charged Particle Density



$$\langle dN_{\text{chg}}/d\eta \rangle = 4.2$$

F “Min-Bias” data on the

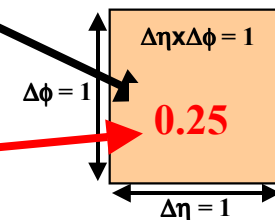
$$\langle dN_{\text{chg}}/d\eta d\phi \rangle = 0.67$$

particles per unit pseudo-rapidity

at 630 and 1,800 GeV. There are about **4.2 charged particles per unit η in “Min-Bias” collisions at 1.8 TeV ($|\eta| < 1$, all P_T).**

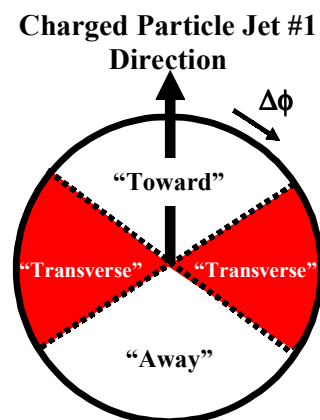
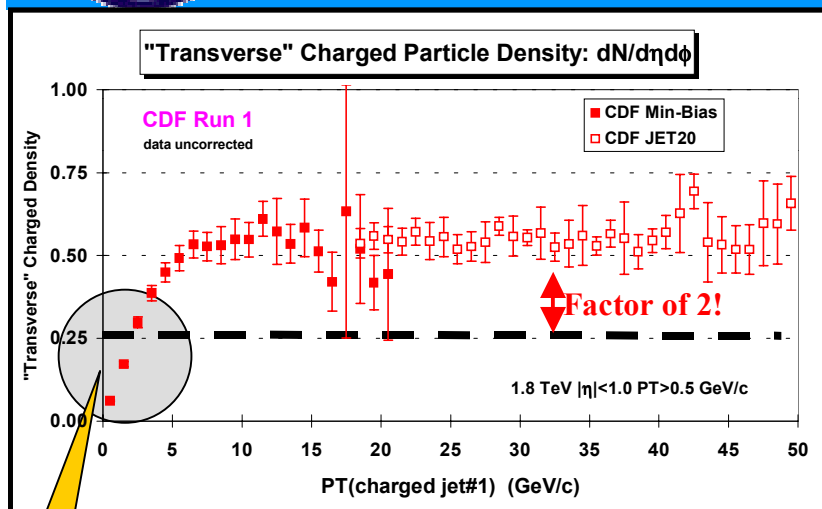
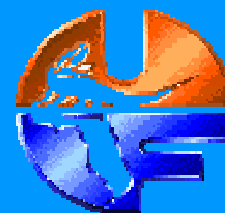
- ➔ Convert to charged particle density, $dN_{\text{chg}}/d\eta d\phi$, by dividing by 2π . There are about **0.67 charged particles per unit η - ϕ in “Min-Bias” collisions at 1.8 TeV ($|\eta| < 1$, all P_T).**

- ➔ There are about **0.25 charged particles per unit η - ϕ in “Min-Bias” collisions at 1.8 TeV ($|\eta| < 1$, $P_T > 0.5$ GeV/c).**





Run 1 Charged Particle Density “Transverse” P_T Distribution

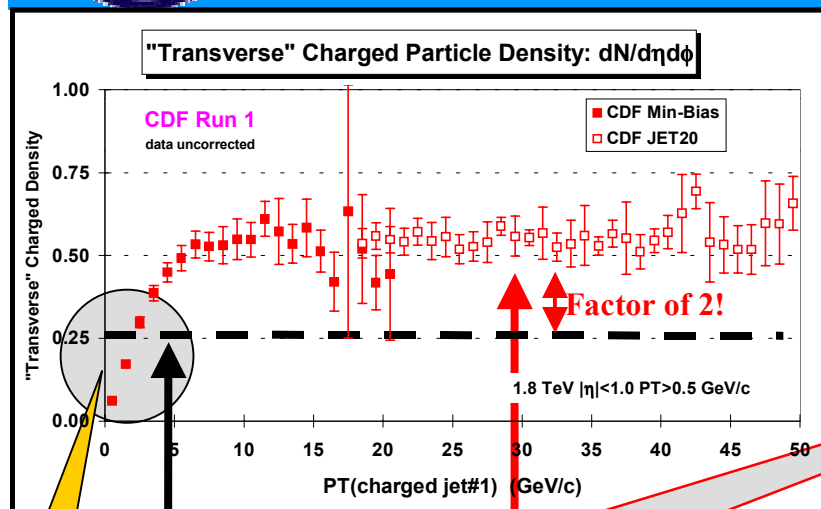
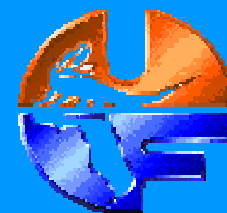


“Min-Bias”

- ➔ Compares the average “transverse” charge particle density with the average “Min-Bias” charge particle density ($|\eta| < 1$, $P_T > 0.5$ GeV). Shows how the “transverse” charge particle density and the Min-Bias charge particle density is distributed in P_T .



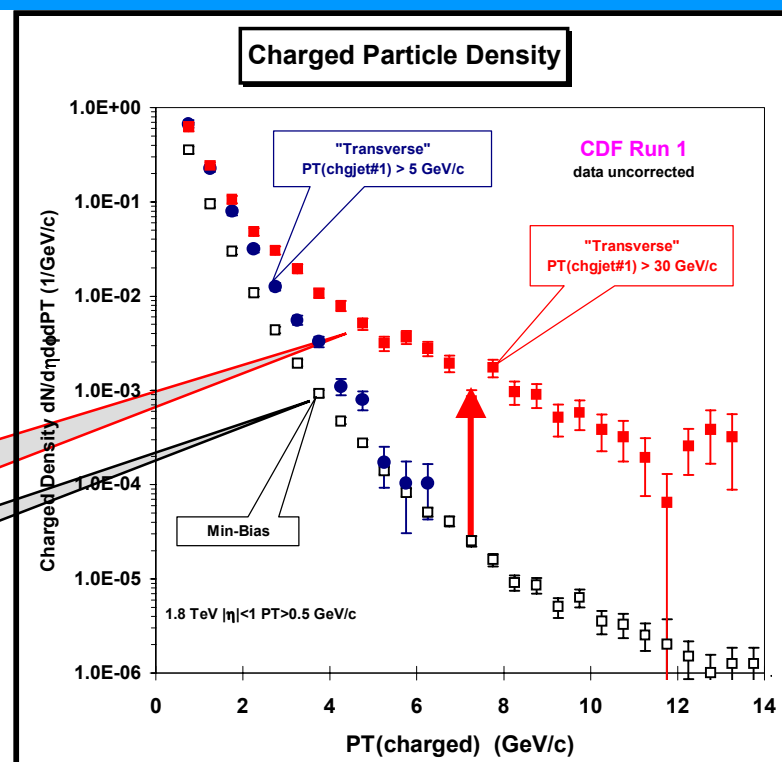
Run 1 Charged Particle Density “Transverse” P_T Distribution



$P_T(\text{charged jet\#1}) > 30$ GeV/c
“Transverse” $\langle dN_{\text{chg}}/d\eta d\phi \rangle = 0.56$

“Min-Bias”

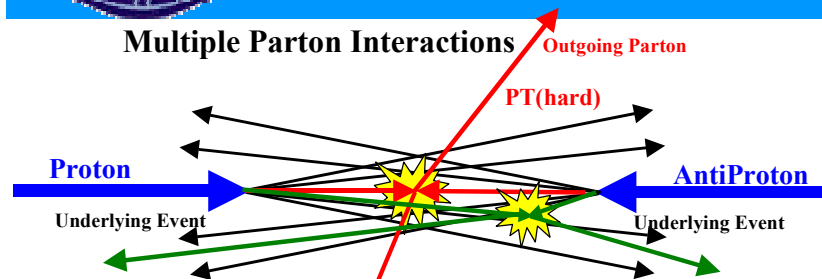
CDF Run 1 Min-Bias data
 $\langle dN_{\text{chg}}/d\eta d\phi \rangle = 0.25$



- ➔ Compares the average “transverse” charge particle density with the average “Min-Bias” charge particle density ($|\eta| < 1$, $P_T > 0.5$ GeV). Shows how the “transverse” charge particle density and the Min-Bias charge particle density is distributed in P_T .



PYTHIA: Multiple Parton Interaction Parameters



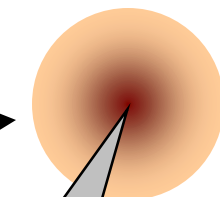
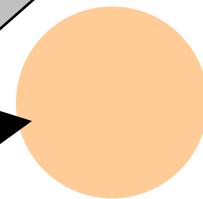
Pythia uses multiple parton interactions to enhance the underlying event.

and now
HERWIG!

Jimmy: MPI
J. M. Butterworth
J. R. Forshaw
M. H. Seymour

Parameter	Value	Description
MSTP(81)	0	Multiple-Parton Scattering off
	1	Multiple-Parton Scattering on
MSTP(82)	1	Multiple interactions assuming the same probability, with an abrupt cut-off $P_{Tmin}=PARP(81)$
	3	Multiple interactions assuming a varying impact parameter and a hadronic matter overlap consistent with a single Gaussian matter distribution, with a smooth turn-off $P_{T0}=PARP(82)$
	4	Multiple interactions assuming a varying impact parameter and a hadronic matter overlap consistent with a double Gaussian matter distribution (governed by $PARP(83)$ and $PARP(84)$), with a smooth turn-off $P_{T0}=PARP(82)$

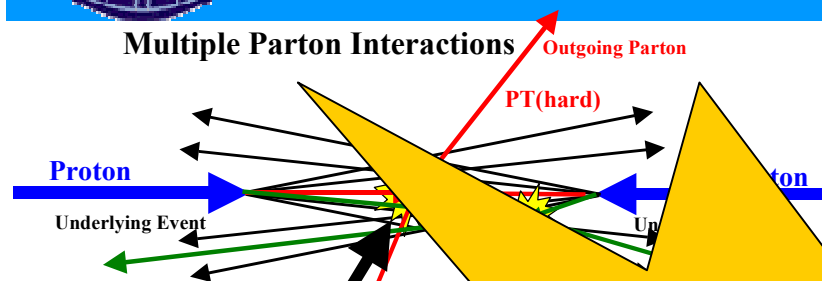
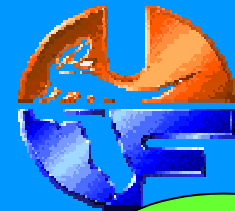
Multiple parton interaction more likely in a hard (central) collision!



Hard Core



PYTHIA: Multiple Parton Interaction Parameters



Pythia uses multiple parton interactions to enhance the underlying event.

and now HERWIG!

Jimmy: MPI
J. M. Butterworth
J. R. Forshaw
M. H. Seymour

Parameter	Value	Description
MSTP(81)	0	Multiple parton interactions (MPI) are not used.
MSTP(81)	1	Multiple parton interactions (MPI) are used.
MSTP(82)	1	Multiple parton interactions (MPI) are used.
MSTP(82)	3	Multiple interactions are used, with a single Gaussian matter distribution and a smooth turn-off $P_{T0}=PARP(82)$.
MSTP(82)	4	Multiple interactions are used, with a varying impact parameter and a hadron matter overlap consistent with a double Gaussian matter distribution (governed by PARP(83) and PARP(84)), with a smooth turn-off $P_{T0}=PARP(82)$.

Note that since the same cut-off parameters govern both the primary hard scattering and the secondary MPI interaction, changing the amount of MPI also changes the amount of hard primary scattering in PYTHIA Min-Bias events!

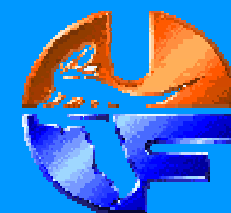
Multiple parton interaction more likely in a hard (central) collision!

Same parameter that cuts-off the hard 2-to-2 parton cross sections!

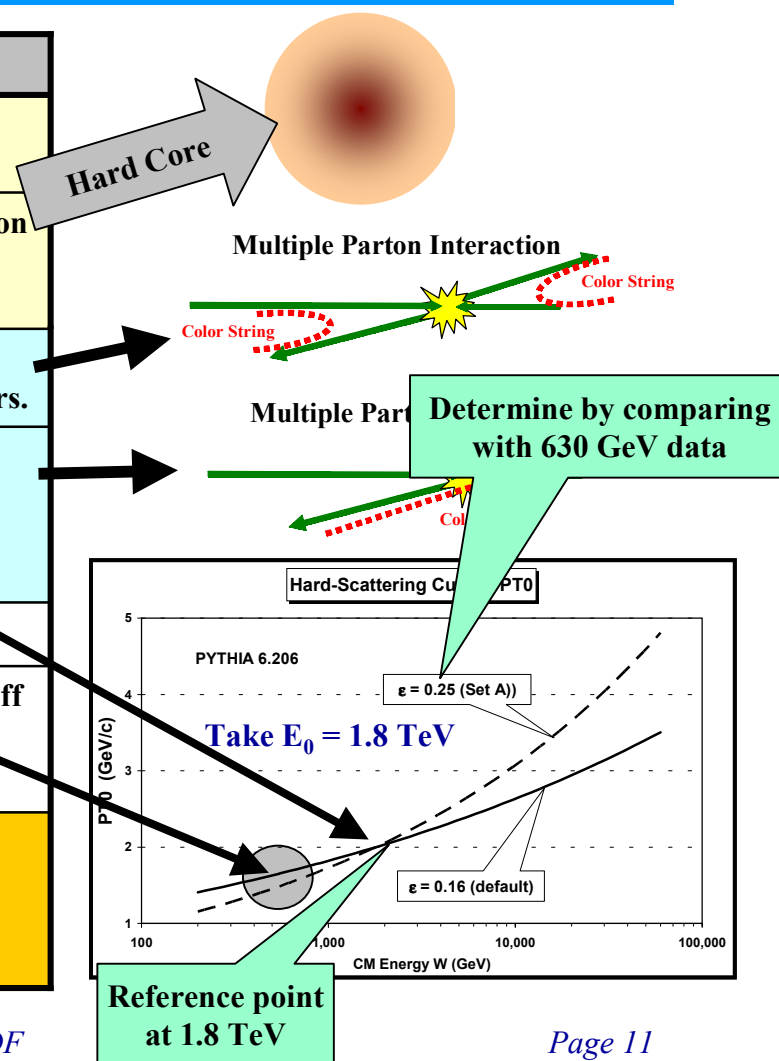
Hard Core



PYTHIA: Multiple Parton Interaction Parameters

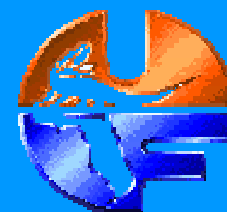


Parameter	Default	Description
PARP(83)	0.5	Double-Gaussian: Fraction of total hadronic matter within PARP(84)
PARP(84)	0.2	Double-Gaussian: Fraction of the overall hadron radius containing the fraction PARP(83) of the total hadronic matter.
PARP(85)	0.33	Probability that the MPI produces two gluons with color connections to the “nearest neighbors.
PARP(86)	0.66	Probability that the MPI produces two gluons either as described by PARP(85) or as a closed gluon loop. The remaining fraction consists of quark-antiquark pairs.
PARP(89)	1 TeV	Determines the reference energy E_0 .
PARP(90)	0.16	Determines the energy dependence of the cut-off P_{T0} as follows $P_{T0}(E_{cm}) = P_{T0}(E_{cm}/E_0)^\epsilon$ with $\epsilon = \text{PARP}(90)$
PARP(67)	1.0	A scale factor that determines the maximum parton virtuality for space-like showers. The larger the value of PARP(67) the more initial-state radiation.





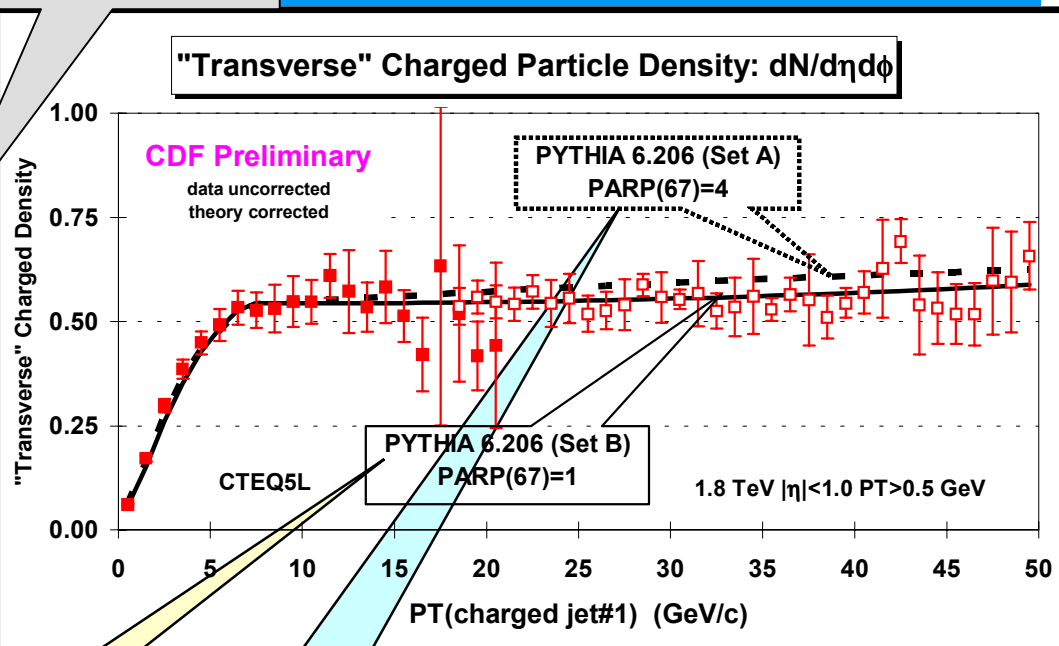
Tuned PYTHIA 6.206



PYTHIA 6.206 CTEQ5L

Parameter	Tune B	Tune A
MSTP(81)	1	1
MSTP(82)	4	4
PARP(82)	1.9 GeV	2.0 GeV
PARP(83)	0.5	0.5
PARP(84)	0.4	0.4
PARP(85)	1.0	0.9
PARP(86)	1.0	0.95
PARP(89)	1.8 TeV	1.8 TeV
PARP(90)	0.25	0.25
PARP(67)	1.0	4.0

Double Gaussian



Plot shows the "Transverse" charged particle density versus $P_T(\text{chgjet\#1})$ compared to the QCD hard scattering predictions of two **tuned** versions of **PYTHIA 6.206** (CTEQ5L, **Set B** (PARP(67)=1) and **Set A** (PARP(67)=4)).

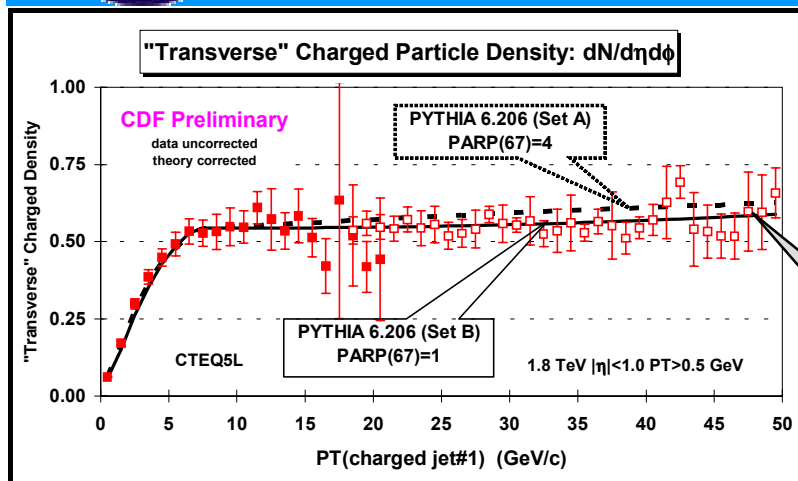
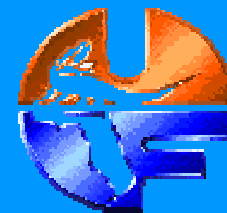
New PYTHIA default
(less initial-state radiation)

Old PYTHIA default
(more initial-state radiation)



Tuned PYTHIA 6.206

“Transverse” P_T Distribution

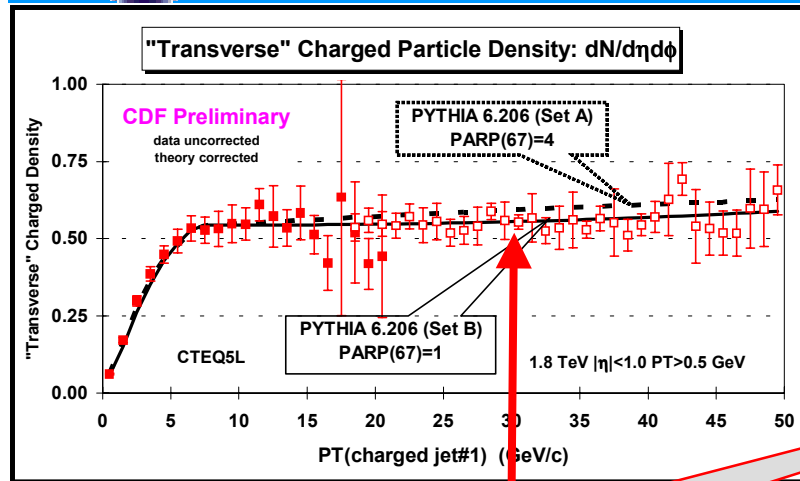


Can we distinguish between
 $\text{PARP}(67)=1$ and $\text{PARP}(67)=4$?
No way! Right!

- ➔ Compares the average “transverse” charge particle density ($|\eta| < 1$, $P_T > 0.5 \text{ GeV}$) versus $P_T(\text{charged jet\#1})$ and the P_T distribution of the “transverse” density, $dN_{\text{chg}}/d\eta d\phi dP_T$ with the QCD Monte-Carlo predictions of two **tuned** versions of **PYTHIA 6.206** ($P_T(\text{hard}) > 0$, CTEQ5L, **Set B** ($\text{PARP}(67)=1$) and **Set A** ($\text{PARP}(67)=4$)).

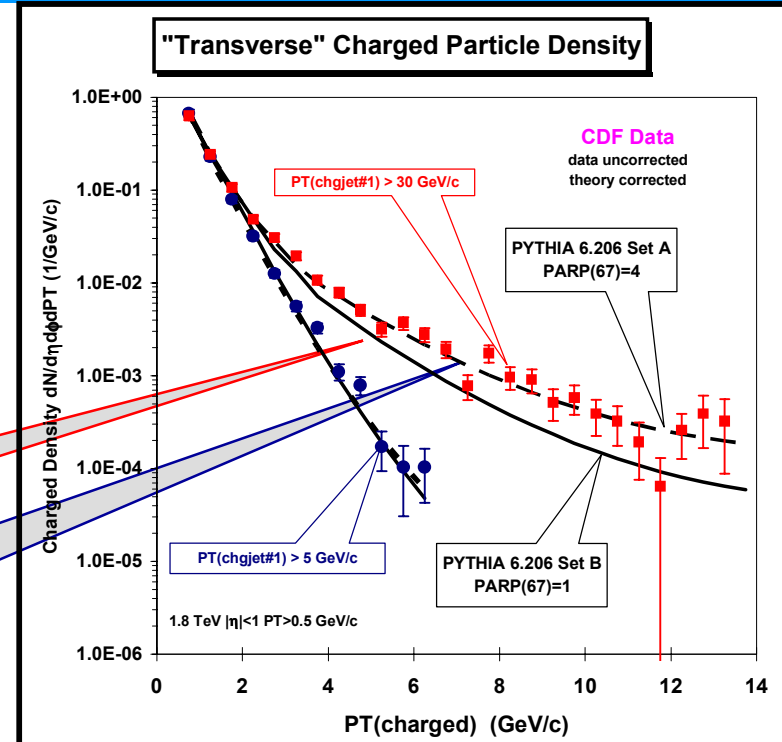


Tuned PYTHIA 6.206 “Transverse” P_T Distribution



$P_T(\text{charged jet\#1}) > 30$ GeV/c

PARP(67)=4.0 (old default) is favored
over PARP(67)=1.0 (new default)!

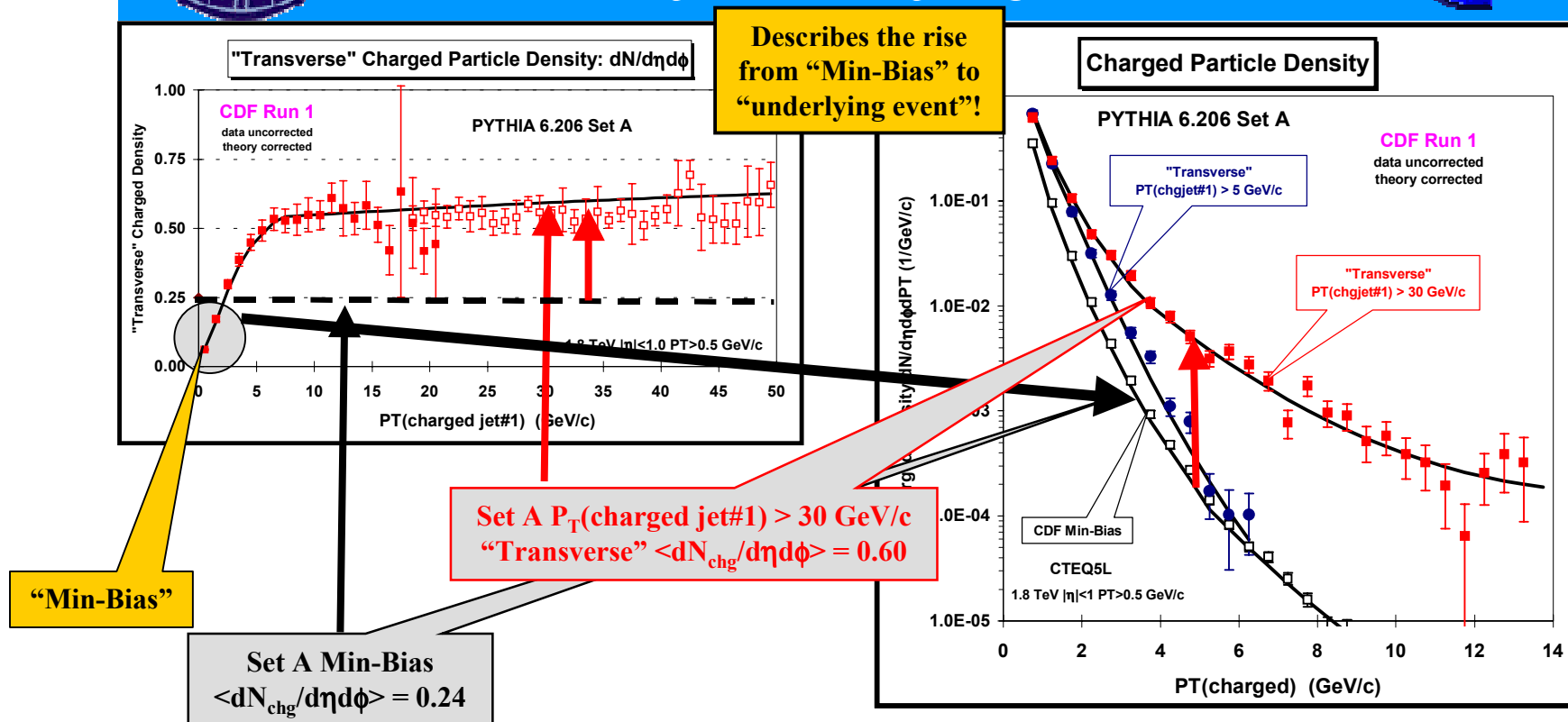
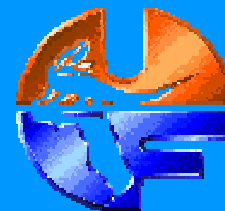


- ➔ Compares the average “transverse” charge particle density ($|\eta| < 1$, $P_T > 0.5$ GeV) versus $P_T(\text{charged jet\#1})$ and the P_T distribution of the “transverse” density, $dN_{\text{chg}}/d\eta d\phi dP_T$ with the QCD Monte-Carlo predictions of two **tuned** versions of **PYTHIA 6.206** ($P_T(\text{hard}) > 0$, CTEQ5L, **Set B** (PARP(67)=1) and **Set A** (PARP(67)=4)).

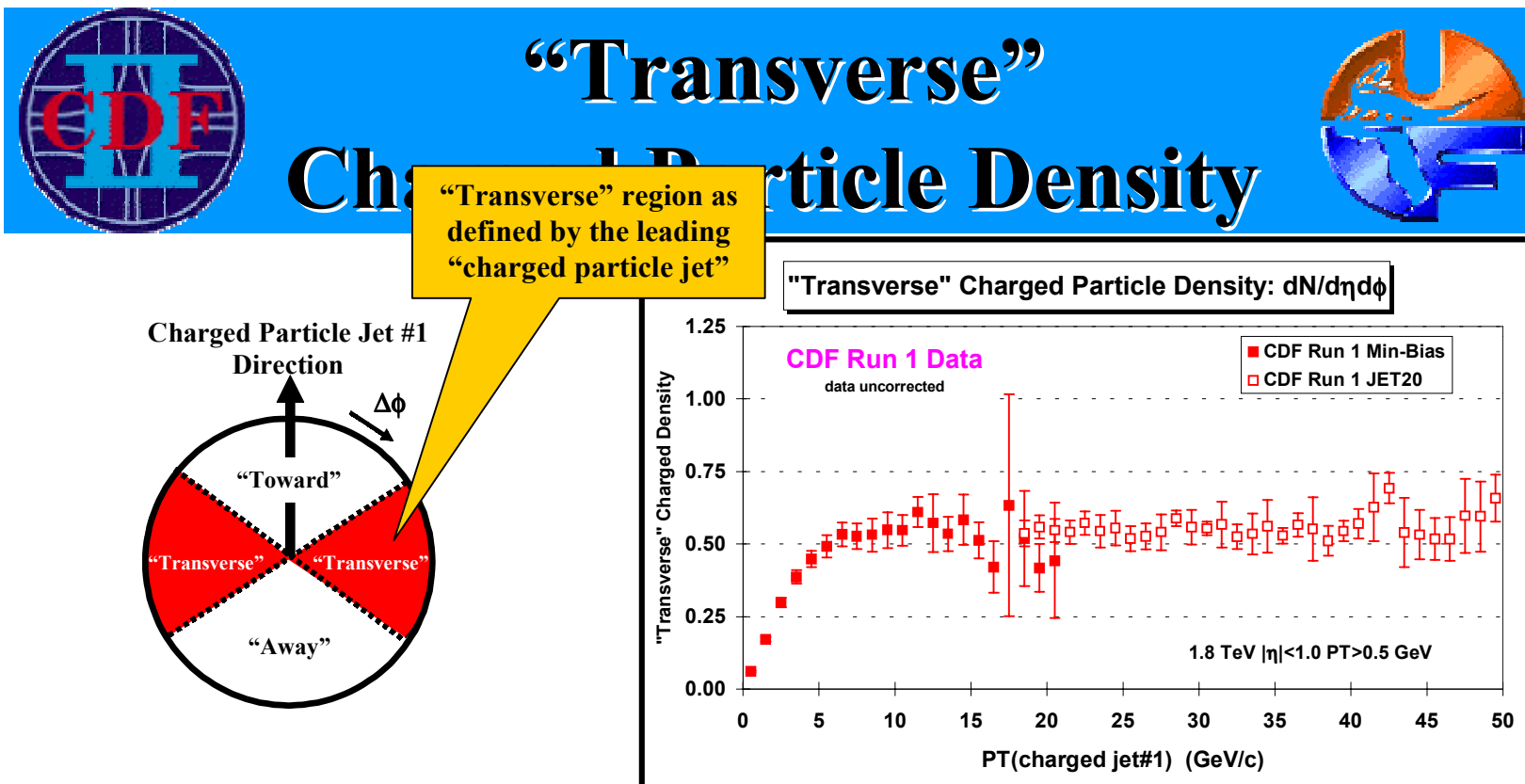


Tuned PYTHIA 6.206

Run 1 Tune A



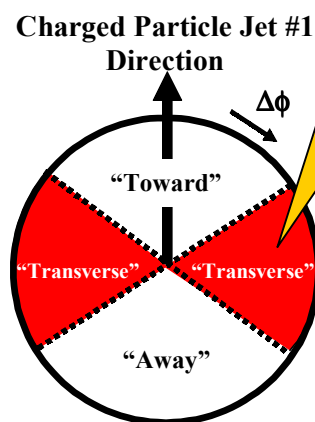
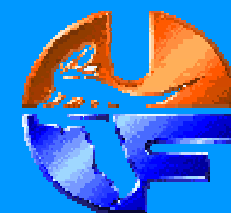
- ➔ Compares the average "transverse" charge particle density ($|\eta| < 1$, $P_T > 0.5$ GeV) versus $P_T(\text{charged jet\#1})$ and the P_T distribution of the "transverse" and "Min-Bias" densities with the QCD Monte-Carlo predictions of a **tuned** version of **PYTHIA 6.206** ($P_T(\text{hard}) > 0$, CTEQ5L, Set A). **Describes "Min-Bias" collisions! Describes the "underlying event"!**



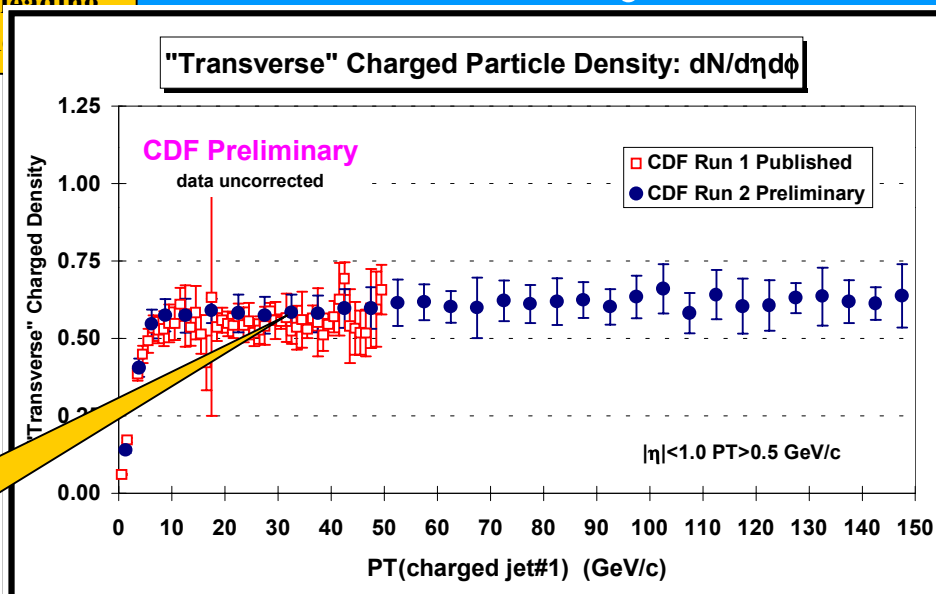
- ➔ Shows the data on the average “transverse” charge particle density ($|\eta| < 1$, $P_T > 0.5$ GeV) as a function of the transverse momentum of the leading charged particle jet from Run 1.



“Transverse” Charged Particle Density



“Transverse” region as defined by the leading “charged particle”

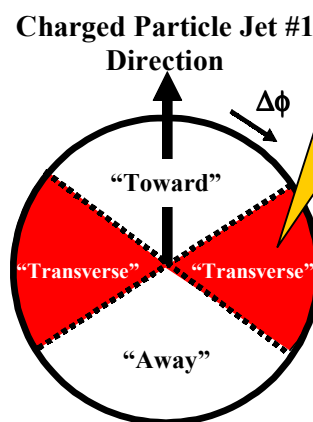
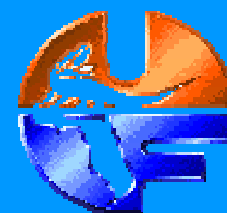


Excellent agreement between Run 1 and 2!

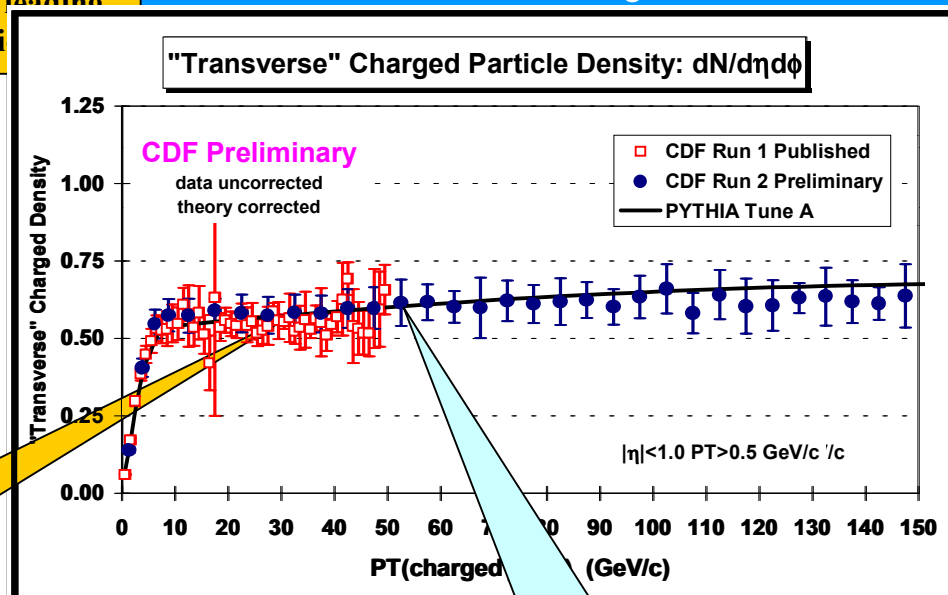
- ➔ Shows the “transverse” charge particle density ($|\eta| < 1$, $P_T > 0.5$ GeV) as a function of the transverse momentum of the leading charged particle jet from Run 1.
- ➔ Compares the Run 2 data (**Min-Bias, JET20, JET50, JET70, JET100**) with Run 1. The errors on the (*uncorrected*) Run 2 data include both statistical and correlated systematic uncertainties.



“Transverse” Charged Particle Density



“Transverse” region as defined by the leading charged particle



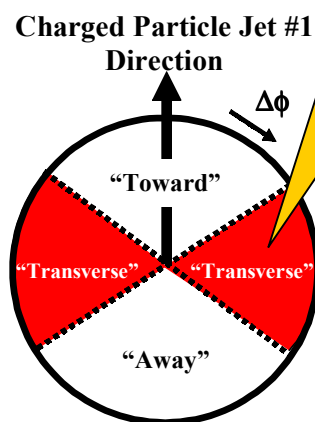
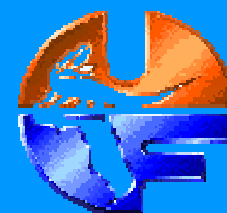
Excellent agreement
between Run 1 and 2!

- ➔ Shows the “transverse” charge particle density ($|\eta| < 1$, $P_T > 0.5$ GeV) as a function of the transverse momentum of the leading charged particle jet from Run 1.
- ➔ Compares the Run 2 data (Min-Bias, JET20, JET50, JET70, JET100) with Run 1. The errors on the (uncorrected) Run 2 data include both statistical and systematic uncertainties.
- ➔ Shows the prediction of **PYTHIA Tune A** at 1.96 TeV after detector simulation (i.e. after CDFSIM).

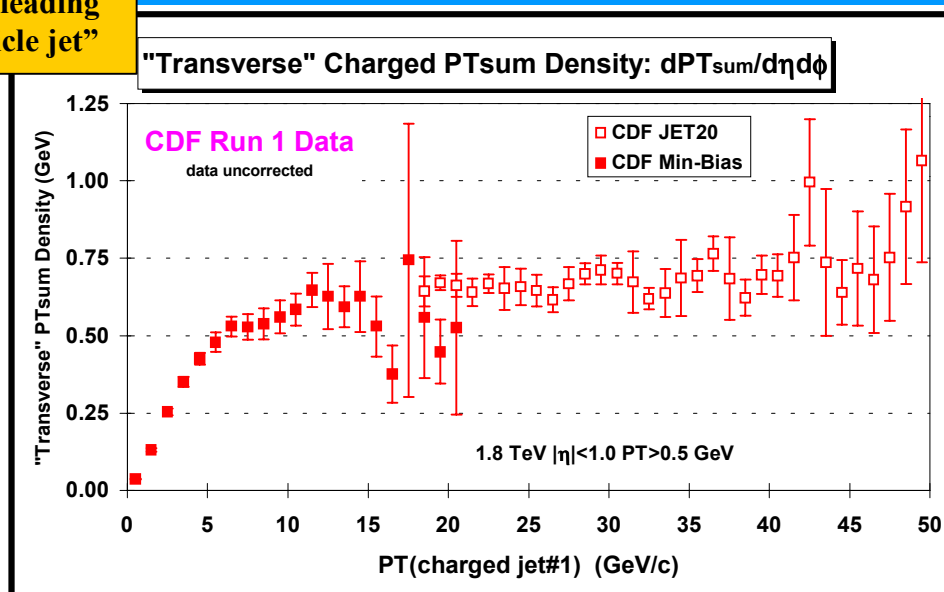
PYTHIA Tune A was tuned to fit the “underlying event” in Run I!



“Transverse” Charged PTsum Density



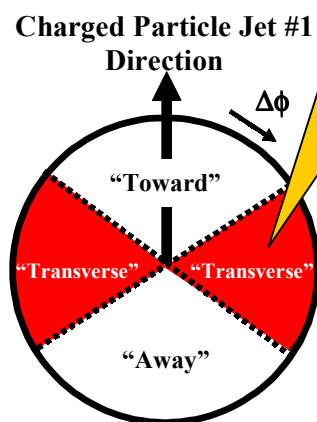
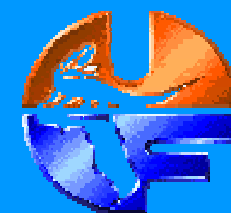
“Transverse” region as
defined by the leading
“charged particle jet”



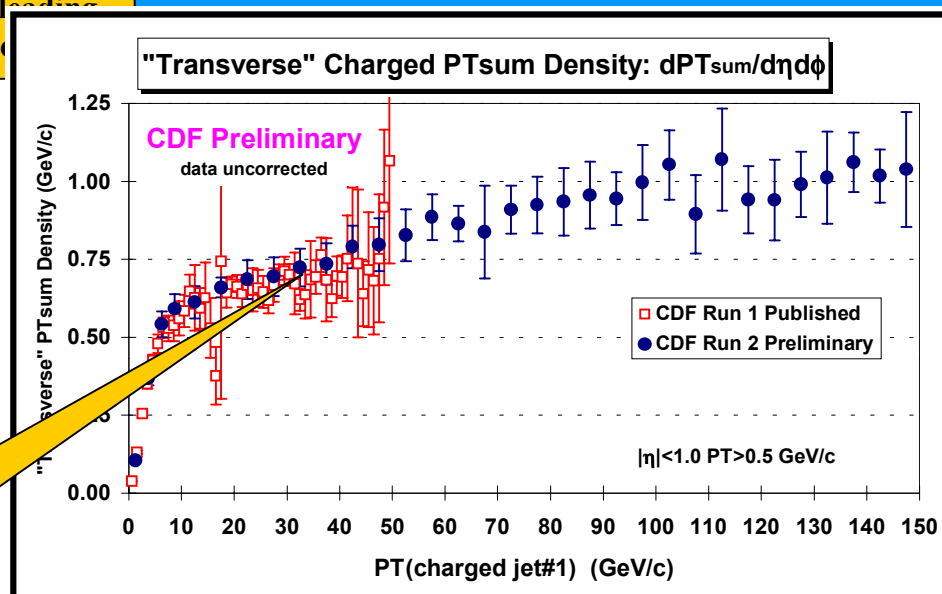
- ➡ Shows the data on the average “transverse” charged PTsum density ($|\eta| < 1$, $P_T > 0.5$ GeV) as a function of the transverse momentum of the leading charged particle jet from Run 1.



“Transverse” Charged PTsum Density



“Transverse” region as defined by the leading “charged particle”

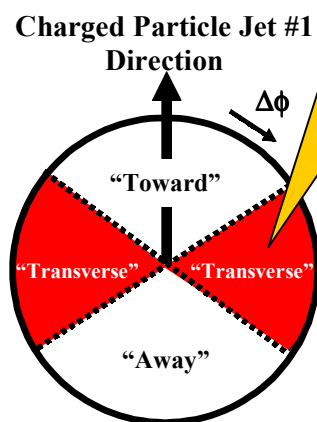
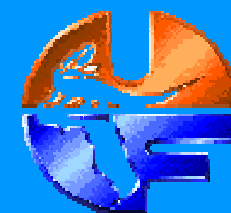


Excellent agreement
between Run 1 and 2!

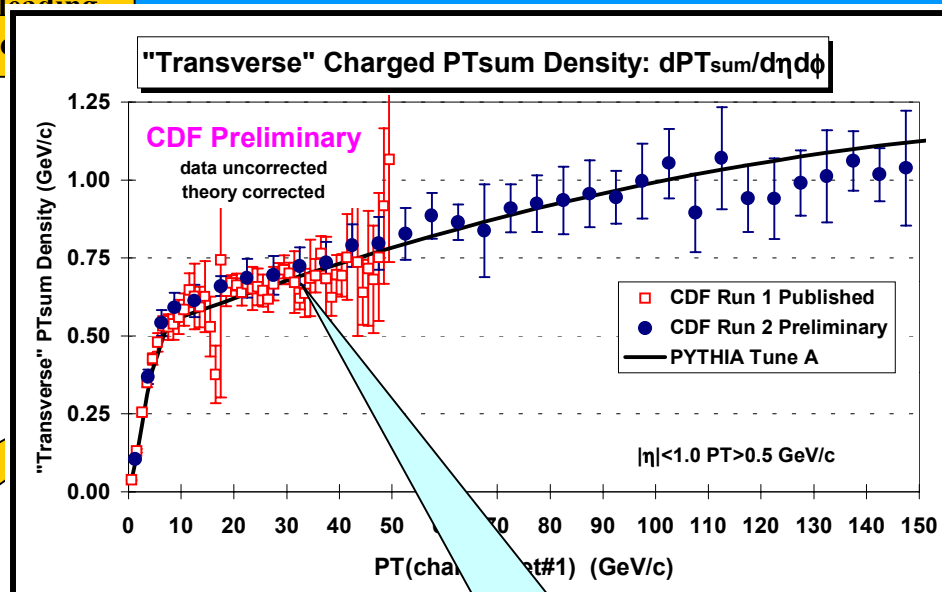
- ➡ Shows that the “transverse” charged PTsum density ($|\eta| < 1$, $P_T > 0.5$ GeV) as a function of the transverse momentum of the leading charged particle jet from Run 1.
- ➡ Compares the Run 2 data (**Min-Bias, JET20, JET50, JET70, JET100**) with Run 1. The errors on the (*uncorrected*) Run 2 data include both statistical and correlated systematic uncertainties.



“Transverse” Charged PTsum Density



“Transverse” region as defined by the leading “charged particle”



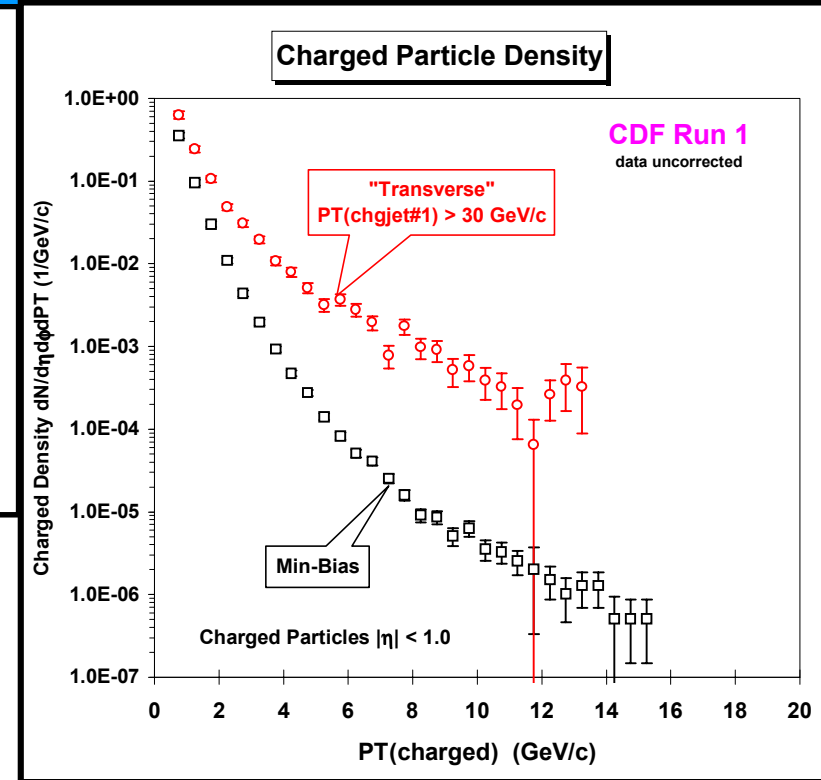
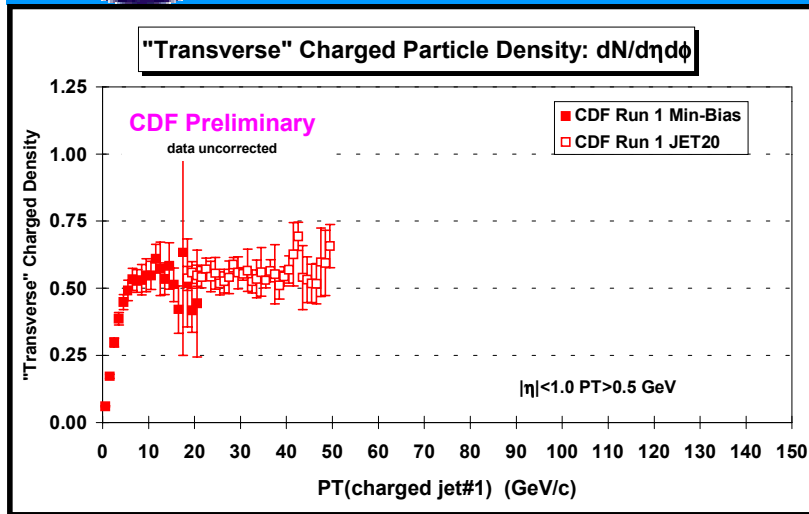
Excellent agreement between Run 1 and 2!

- ➔ Shows the “transverse” charged PTsum density ($|\eta| < 1$, $P_T > 0.5$ GeV) as a function of the transverse momentum of the leading charged particle jet from Run 1.
- ➔ Compares the Run 2 data (Min-Bias, JET20, JET50, JET70, JET100) with Run 1. The errors on the (*uncorrected*) Run 2 data include both statistical and systematic uncertainties.
- ➔ Shows the prediction of **PYTHIA Tune A** at 1.96 TeV after detector simulation (*i.e.* after CDFSIM).

PYTHIA Tune A was tuned to fit the “underlying event” in Run I!



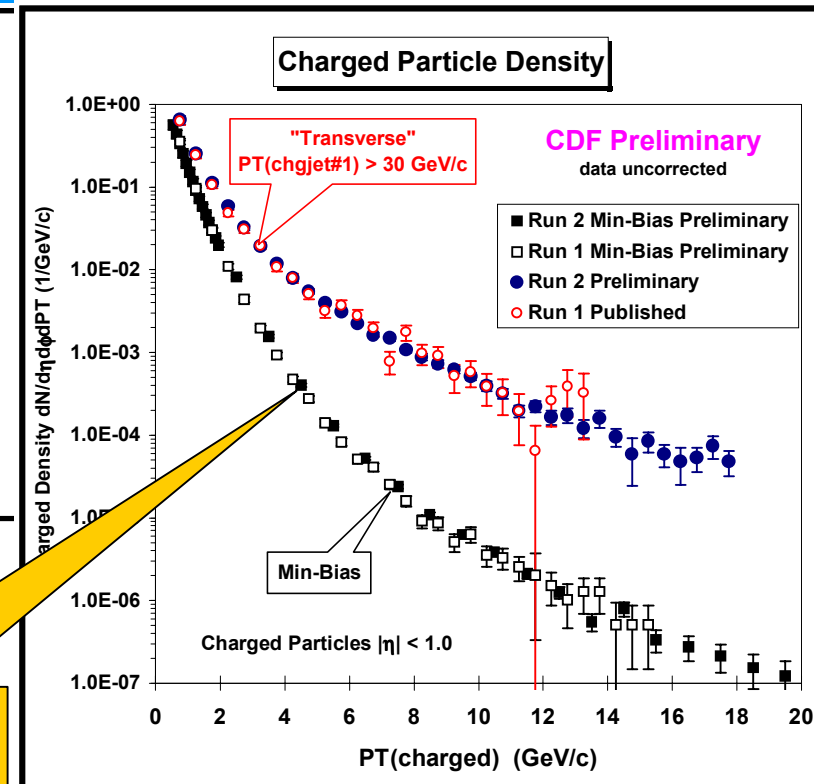
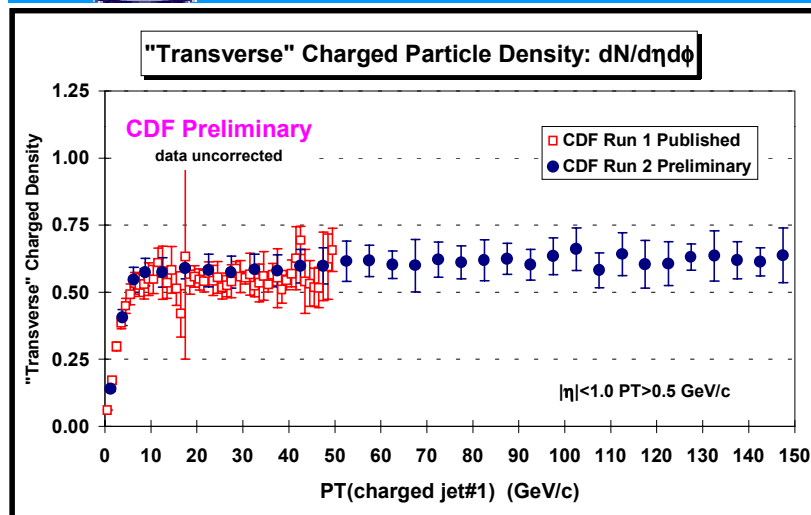
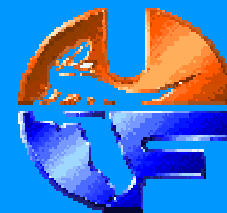
Charged Particle Density “Transverse” P_T Distribution



➔ Compares the average “transverse” charge particle density ($|\eta| < 1$, $P_T > 0.5$ GeV) versus $P_T(\text{charged jet\#1})$ with the P_T distribution of the “transverse” density, $dN_{\text{chg}}/d\eta d\phi dP_T$. Shows how the “transverse” charge particle density is distributed in P_T .



Charged Particle Density “Transverse” P_T Distribution



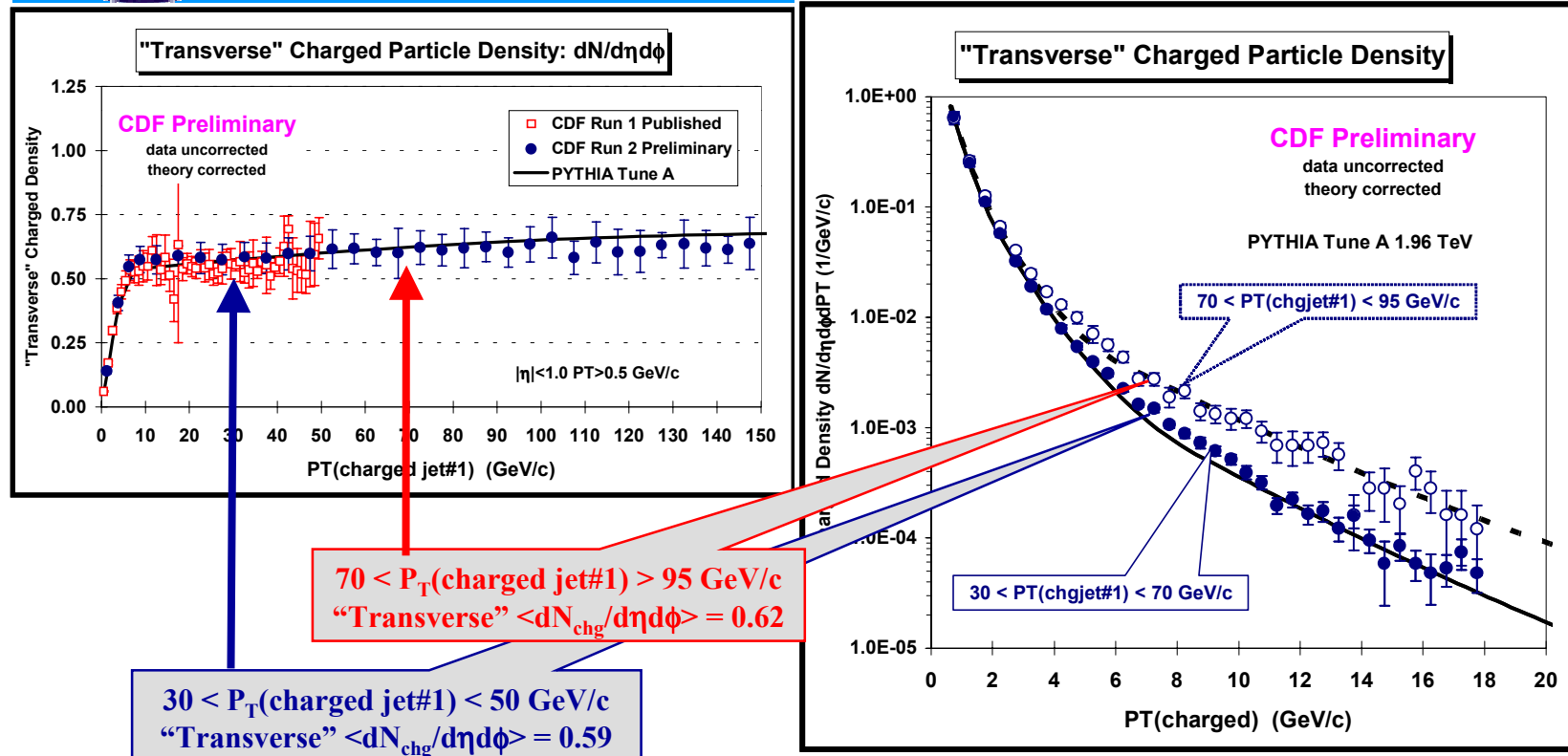
➔ Compares the average “transverse” charge particle density ($|\eta| < 1$, $P_T > 0.5$ GeV) versus $P_T(\text{charged jet\#1})$ with the P_T distribution of the charged particle density, $dN_{\text{chg}}/d\eta d\phi dP_T$. Shows how the “transverse” charge particle density is distributed in P_T .

Excellent agreement
between Run 1 and 2!

➔ Compares the Run 2 data (Min-Bias, JET20, JET50, JET70, JET100) with Run 1.



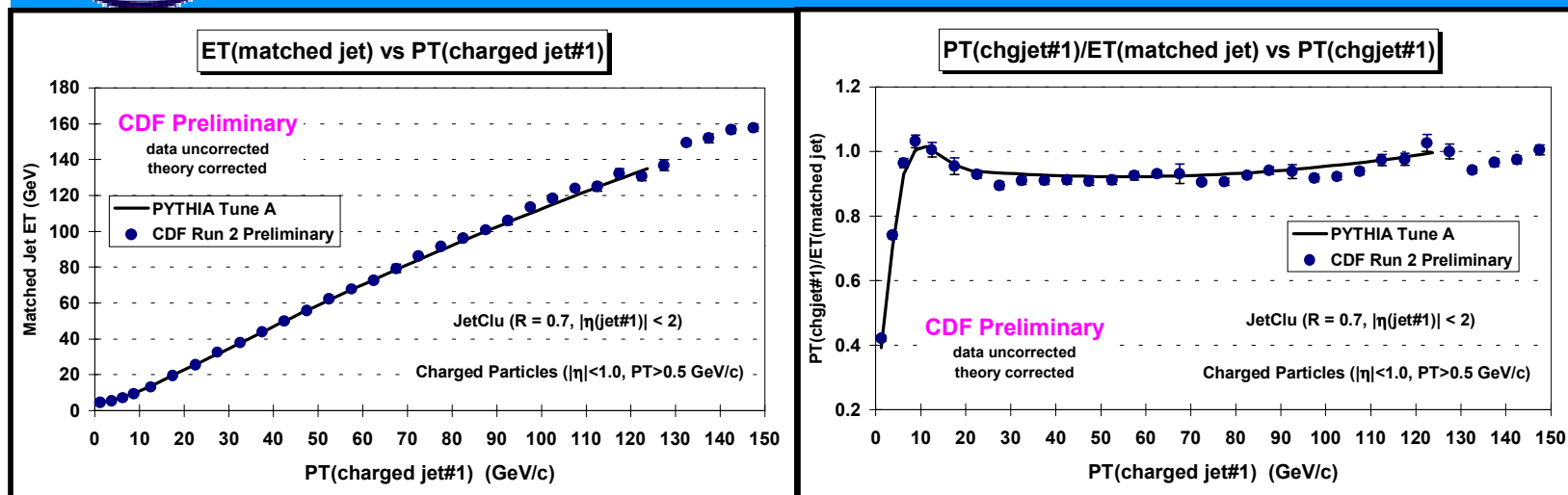
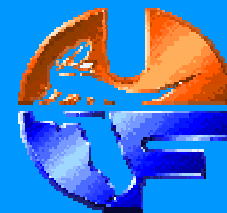
Charged Particle Density “Transverse” P_T Distribution



- ➔ Compares the average “transverse” charge particle density ($|\eta| < 1$, $P_T > 0.5$ GeV) versus $P_T(\text{charged jet\#1})$ with the P_T distribution of the “transverse” density, $dN_{\text{chg}}/d\eta d\phi dP_T$.
- ➔ Shows the prediction of **PYTHIA Tune A** at 1.96 TeV after detector simulation (*i.e.* after CDFSIM).



Relationship Between “Calorimeter” and “Charged Particle” Jets



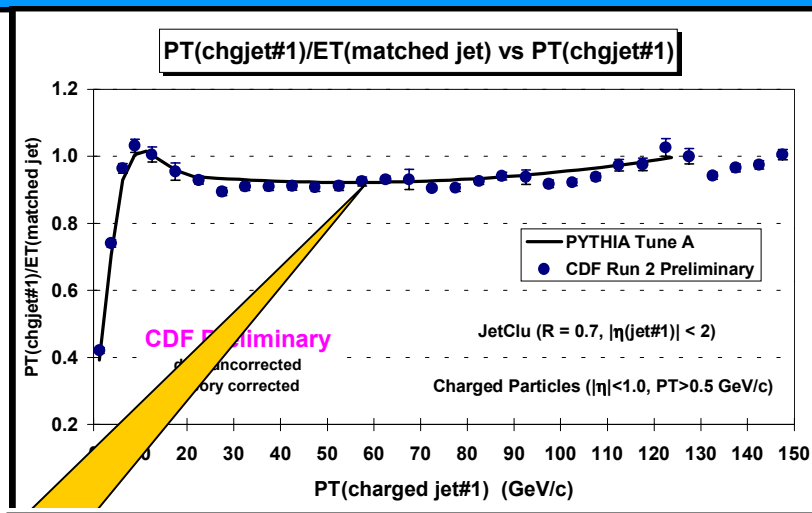
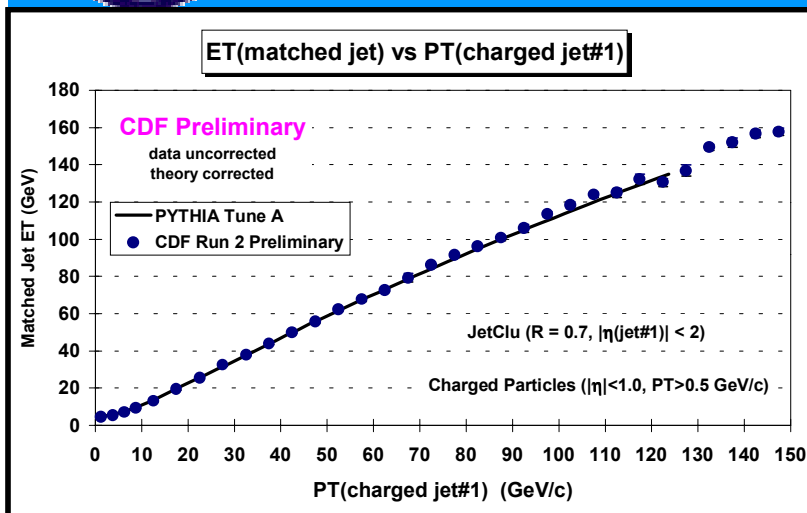
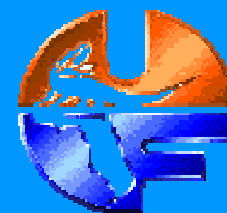
➔ Shows the “**matched**” JetClu jet E_T versus the transverse momentum of the leading “**charged particle jet**” (**closest jet within $R = 0.7$ of the leading chgjet**).

➔ Shows the ratio of $P_T(\text{chgjet\#1})$ to the “**matched**” JetClu jet E_T versus $P_T(\text{chgjet\#1})$.

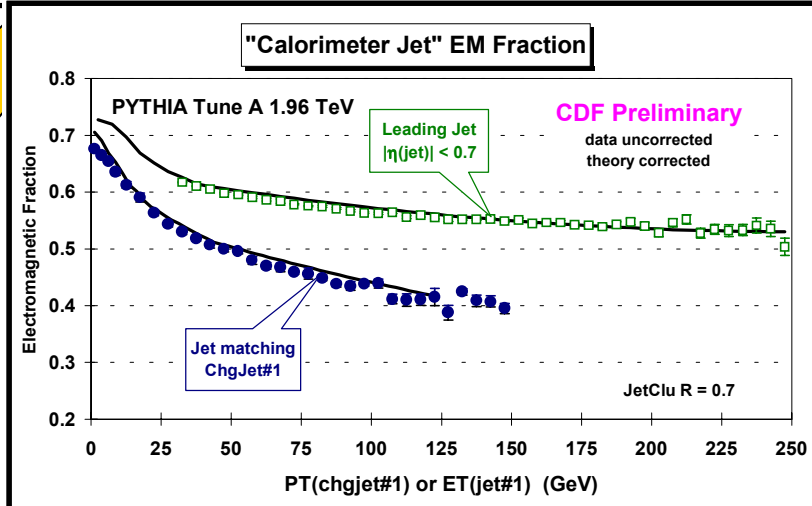
➔ Shows the EM fraction of the “**matched**” JetClu jet and the EM fraction of a typical JetClu jet.



Relationship Between “Calorimeter” and “Charged Particle” Jets

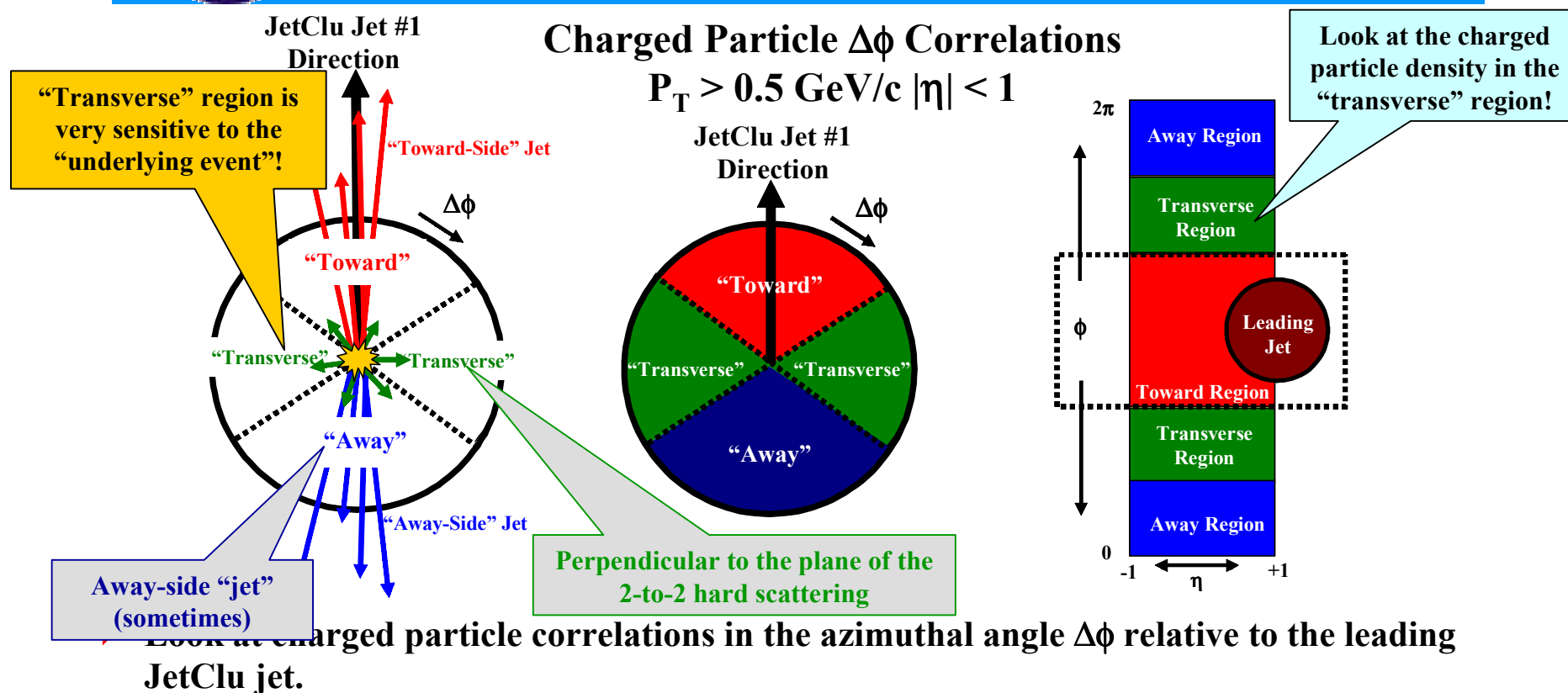
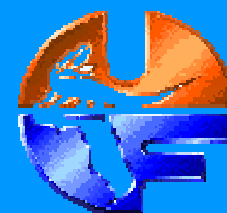


- Shows the “matched” JetClu jet E_T versus the transverse momentum of the leading “charged particle jet” (closest charged jet within $R = 0.7$ of the leading jet).
- Shows the ratio of the leading charged particle jet transverse momentum to the matched JetClu jet E_T . The leading chgjet comes from a JetClu jet that is, on the average, about 90% charged!

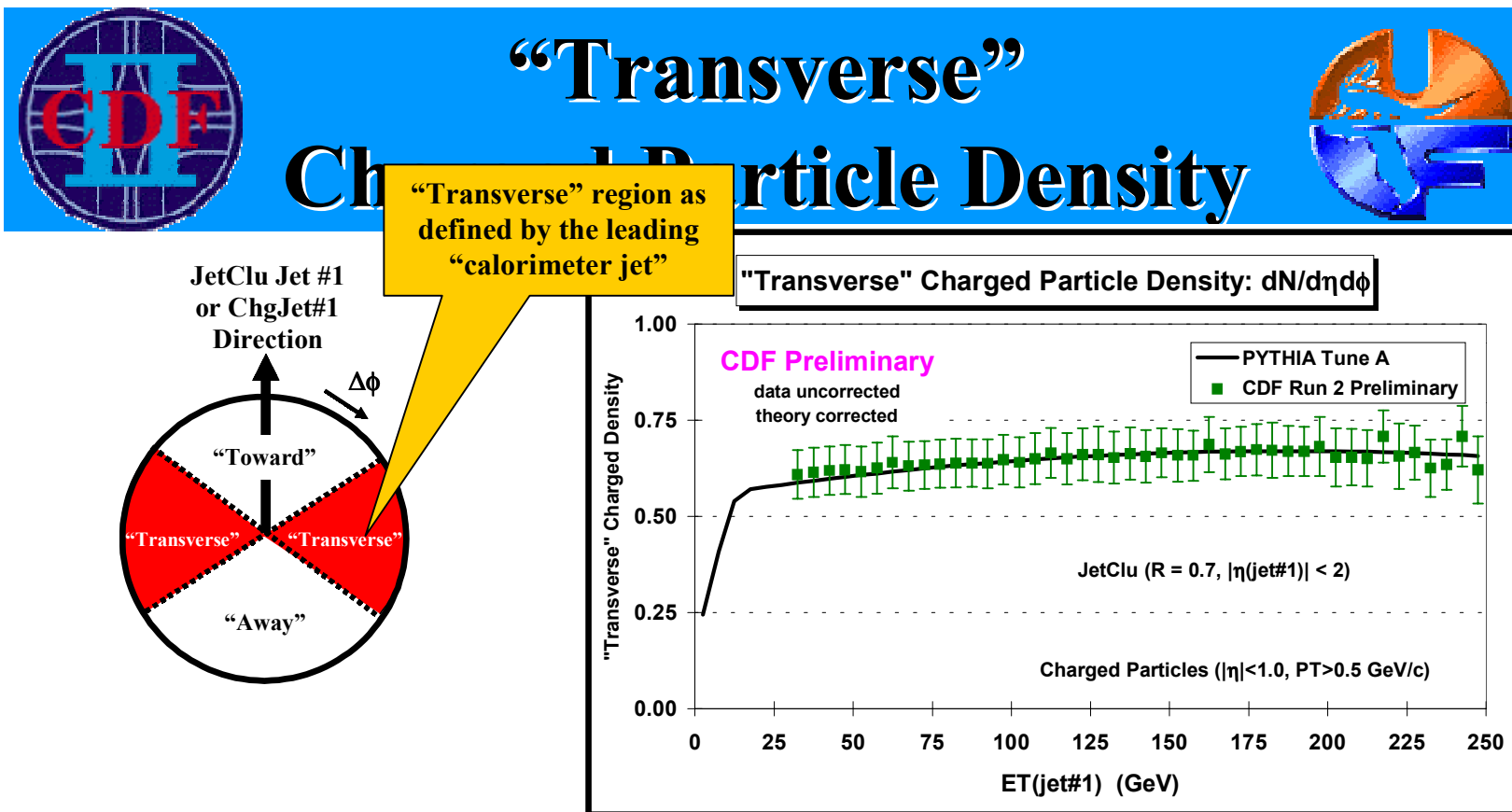




“Underlying Event” as defined by “Calorimeter Jets”



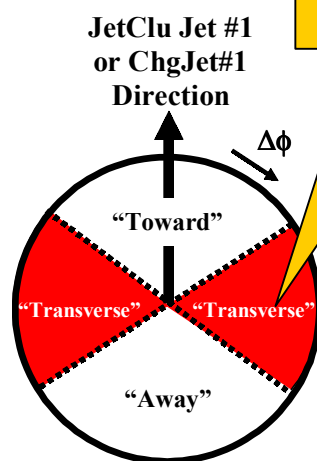
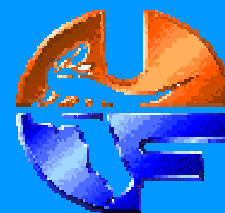
- ➡ Define $|\Delta\phi| < 60^\circ$ as “Toward”, $60^\circ < |\Delta\phi| < 120^\circ$ as “Transverse”, and $|\Delta\phi| > 120^\circ$ as “Away”.
- ➡ All three regions have the same size in η - ϕ space, $\Delta\eta \times \Delta\phi = 2 \times 120^\circ = 4\pi/3$.



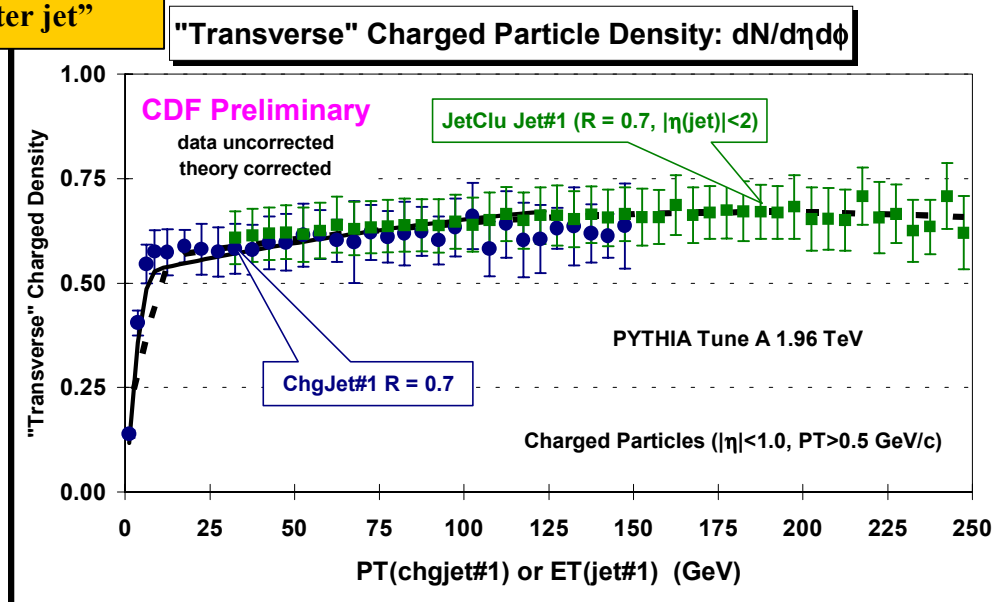
- ➡ Shows the data on the average “transverse” charge particle density ($|\eta| < 1$, $PT > 0.5$ GeV) as a function of the transverse energy of the leading JetClu jet ($R = 0.7$, $|\eta(jet)| < 2$) from Run 2, compared with **PYTHIA Tune A** after CDFSIM.



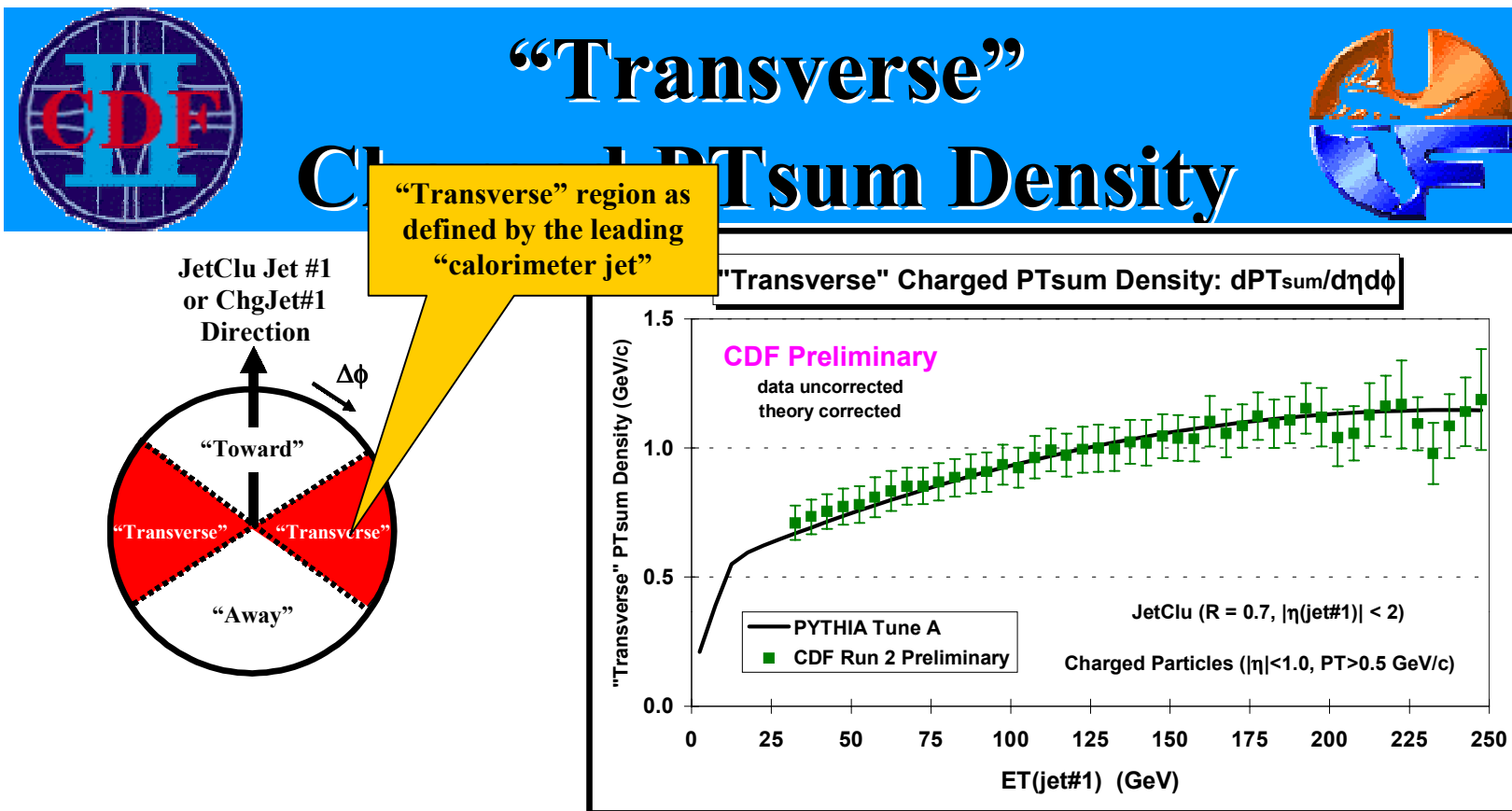
“Transverse” Charged Particle Density



“Transverse” region as defined by the leading “calorimeter jet”



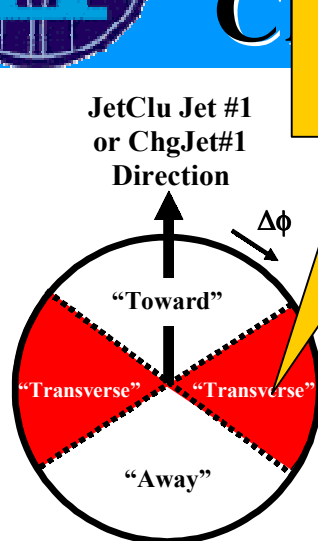
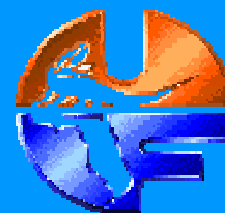
- ➡ Shows the data on the average “transverse” charge particle density ($|\eta| < 1, PT > 0.5 \text{ GeV}$) as a function of the transverse energy of the leading JetClu jet ($R = 0.7, |\eta(\text{jet})| < 2$) from Run 2, compared with **PYTHIA Tune A** after CDFSIM.
- ➡ Compares the “transverse” region of the leading “charged particle jet”, chgjet#1, with the “transverse” region of the leading “calorimeter jet” (JetClu $R = 0.7$), jet#1.



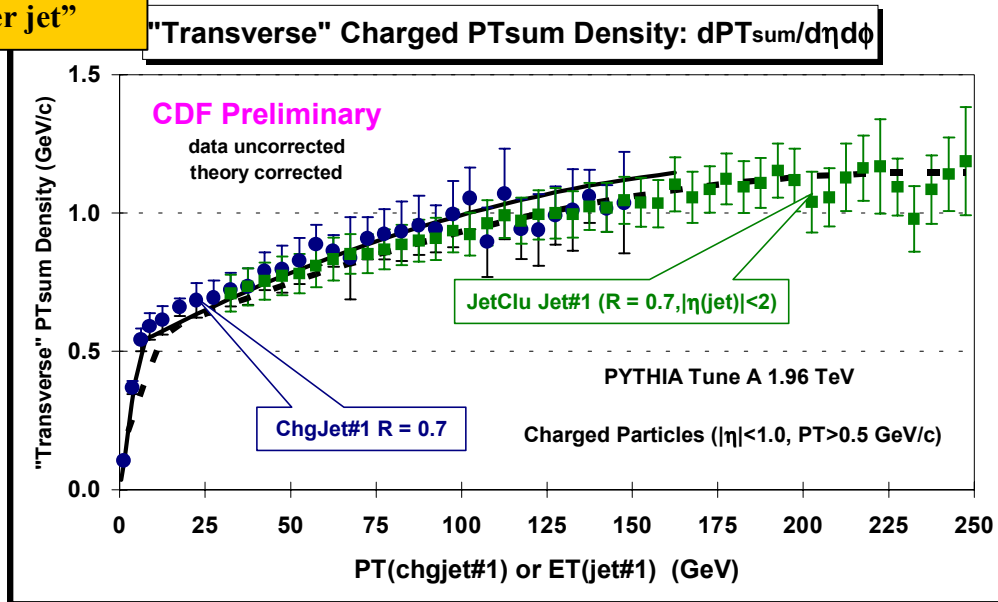
- ➡ Shows the data on the average “transverse” charged PTsum density ($|\eta| < 1, PT > 0.5$ GeV) as a function of the transverse energy of the leading JetClu jet ($R = 0.7, |\eta(jet)| < 2$) from Run 2, compared with **PYTHIA Tune A** after CDFSIM.



“Transverse” Charged PTsum Density



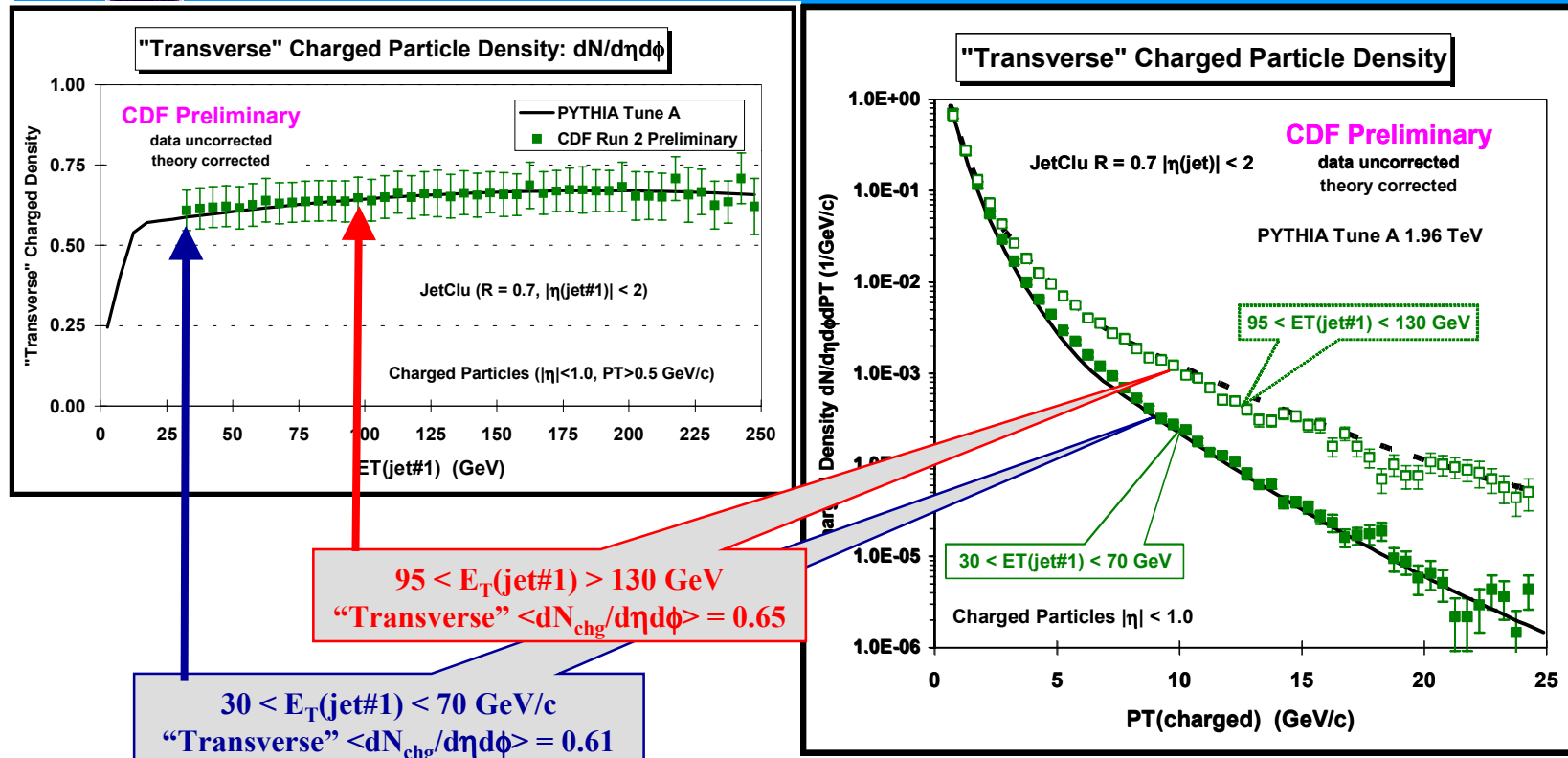
“Transverse” region as defined by the leading “calorimeter jet”



- ➡ Shows the data on the average “transverse” charged PTsum density ($|\eta| < 1, PT > 0.5 \text{ GeV}$) as a function of the transverse energy of the leading JetClu jet ($R = 0.7, |\eta(jet)| < 2$) from Run 2, compared with **PYTHIA Tune A** after CDFSIM.
- ➡ Compares the “transverse” region of the leading “charged particle jet”, chgjet#1, with the “transverse” region of the leading “calorimeter jet” (JetClu $R = 0.7$), jet#1.



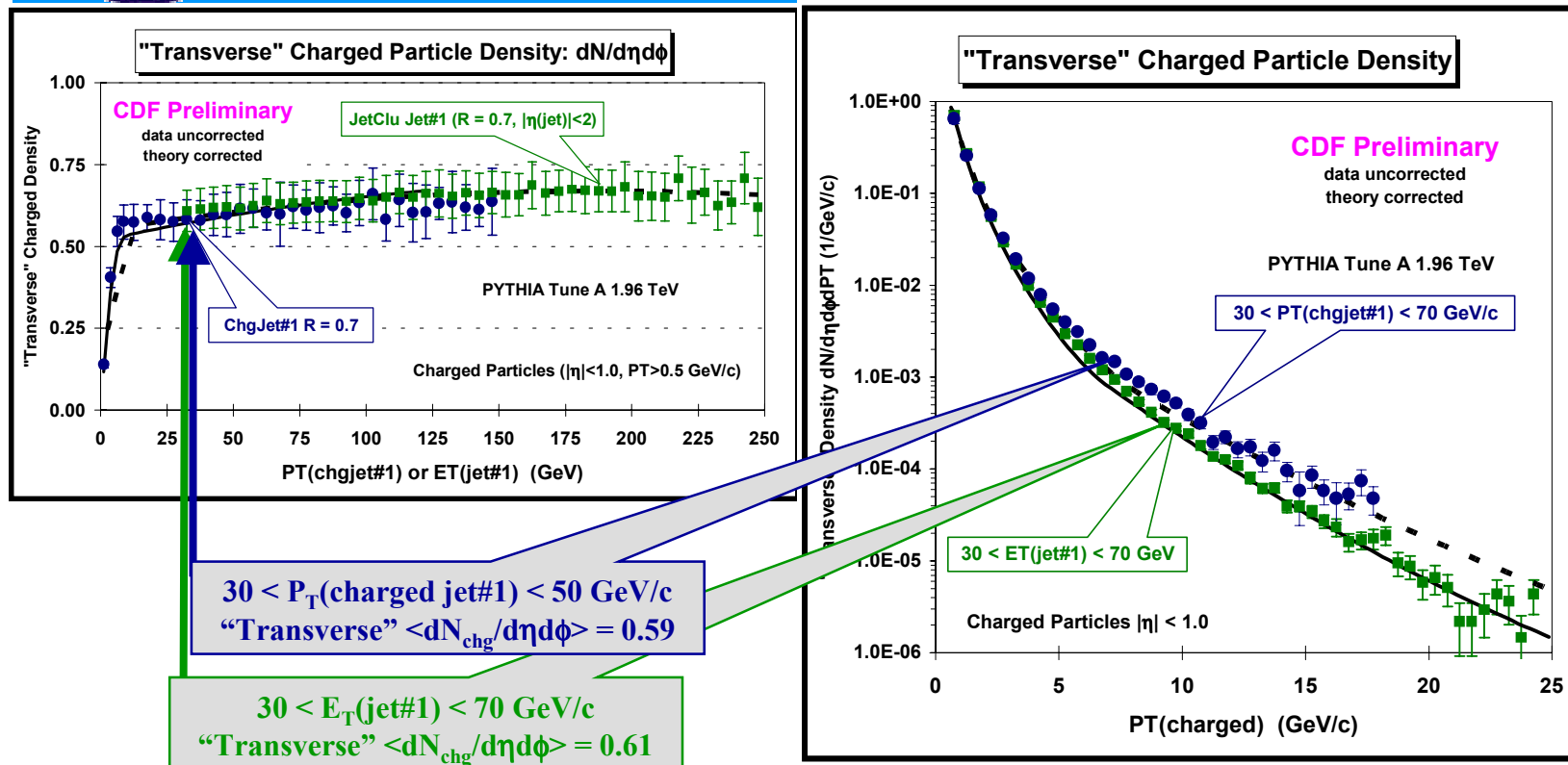
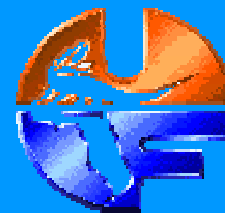
Charged Particle Density “Transverse” P_T Distribution



- ➔ Compares the average “transverse” charge particle density ($|\eta| < 1, P_T > 0.5 \text{ GeV}$) versus $E_T(\text{jet}\#1)$ with the P_T distribution of the “transverse” density, $dN_{\text{chg}}/d\eta d\phi dP_T$.
- ➔ Shows the prediction of **PYTHIA Tune A** at 1.96 TeV after detector simulation (*i.e.* after CDFSIM).



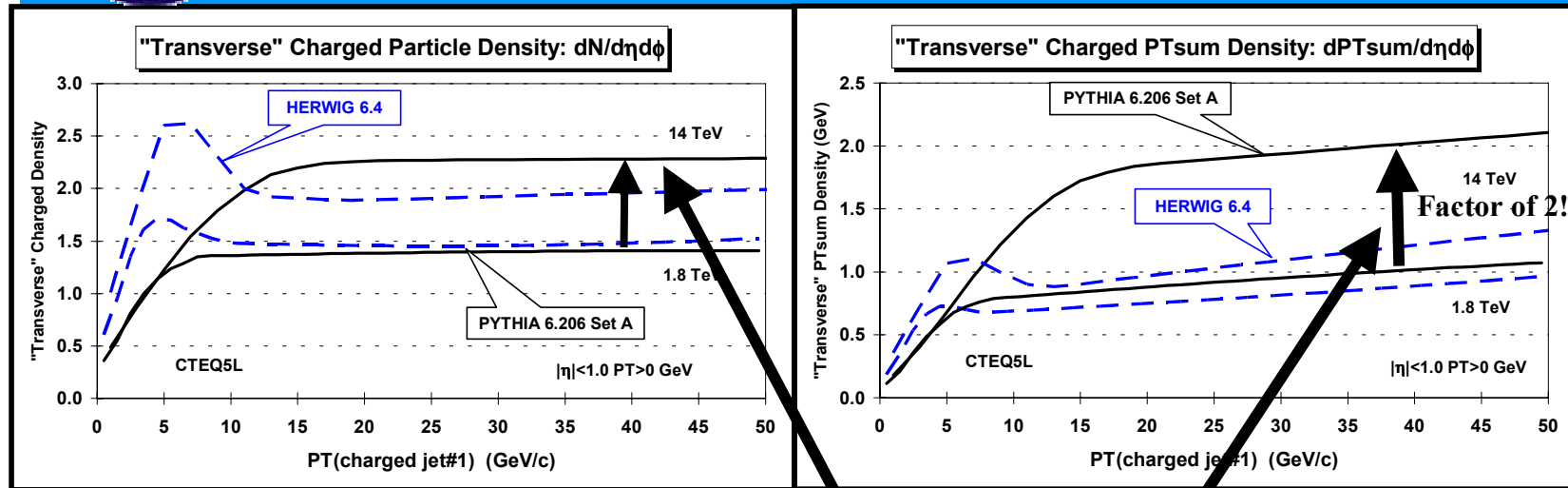
Charged Particle Density “Transverse” P_T Distribution



- ➔ Compares the average “transverse” as defined by “calorimeter jets” (JetClu $R = 0.7$) with the “transverse” region defined by “charged particle jets”.
- ➔ Shows the prediction of **PYTHIA Tune A** at 1.96 TeV after detector simulation (*i.e.* after CDFSIM).



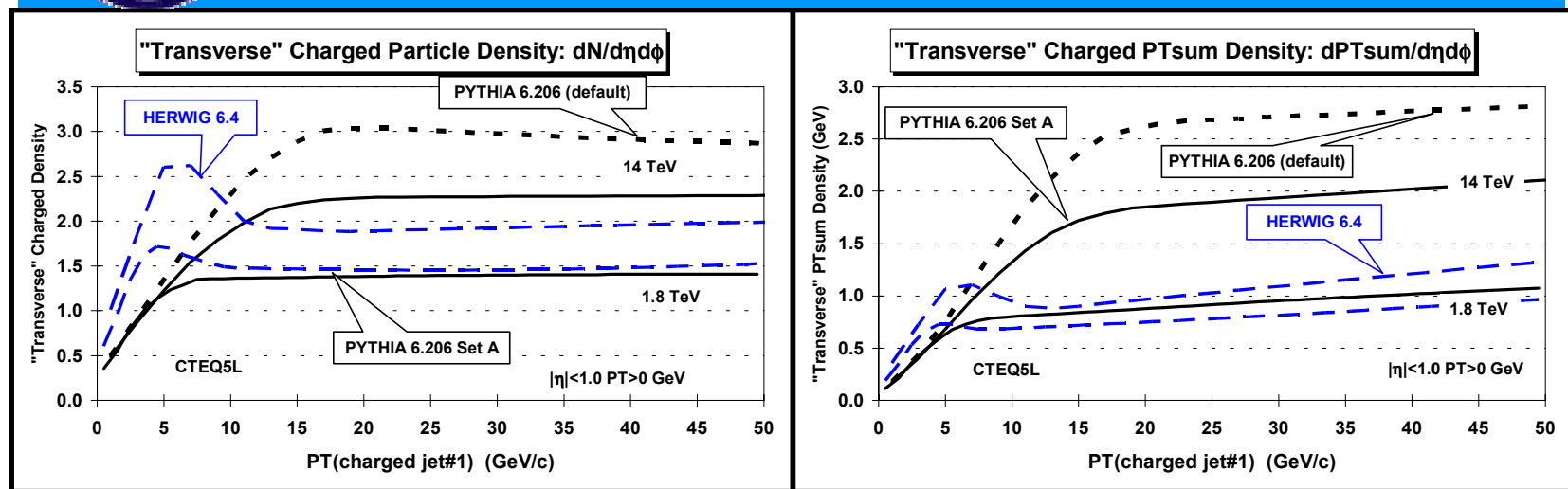
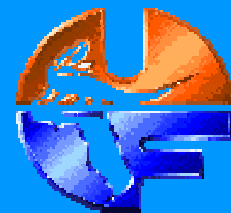
Tuned PYTHIA (Set A) LHC Predictions



- ➔ Shows the average “transverse” charge particle and PT_{sum} density ($|\eta| < 1$, $P_T > 0$) versus P_T (charged jet#1) predicted by HERWIG 6.4 ($P_T(hard) > 3$ GeV/c, CTEQ5L), and a **tuned** versions of **PYTHIA 6.206** ($P_T(hard) > 0$, CTEQ5L, **Set A**) at 1.8 TeV and 14 TeV.
- ➔ At 14 TeV tuned PYTHIA (**Set A**) predicts roughly **2.3 charged particles per unit η - ϕ** ($P_T > 0$) in the “transverse” region (**14 charged particles per unit η**) which is larger than the HERWIG prediction.
- ➔ At 14 TeV tuned PYTHIA (**Set A**) predicts roughly **2 GeV/c charged PT_{sum} per unit η - ϕ** ($P_T > 0$) in the “transverse” region at $P_T(chgjet\#1) = 40$ GeV/c which is a **factor of 2 larger than at 1.8 TeV** and much larger than the HERWIG prediction.



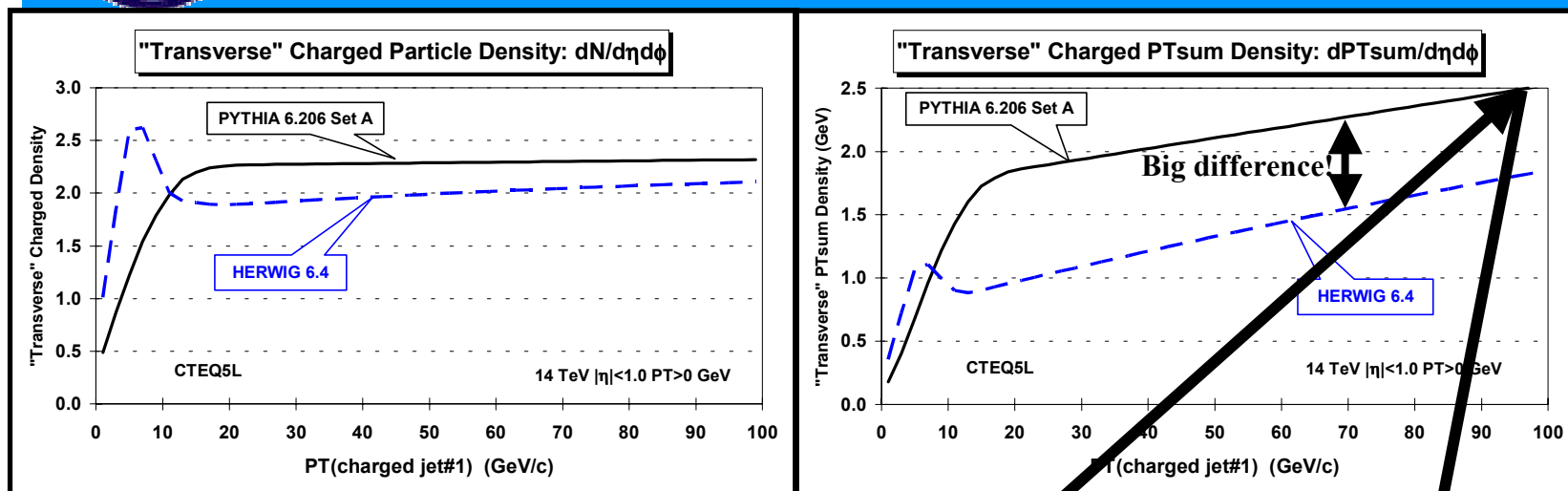
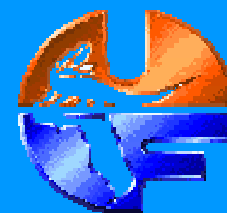
Tuned PYTHIA (Set A) LHC Predictions



- ➡ Shows the average “transverse” charge particle and PT_{sum} density ($|\eta| < 1$, $P_T > 0$) versus $P_T(\text{charged jet\#1})$ predicted by HERWIG 6.4 ($P_T(\text{hard}) > 3$ GeV/c, CTEQ5L). and a **tuned** versions of **PYTHIA 6.206** ($P_T(\text{hard}) > 0$, CTEQ5L, **Set A**) at 1.8 TeV and 14 TeV. Also shown is the 14 TeV prediction of PYTHIA 6.206 with the default value $\epsilon = 0.16$.
- ➡ Tuned PYTHIA (**Set A**) predicts roughly 2.3 charged particles per unit η - ϕ ($P_T > 0$) in the “transverse” region (14 charged particles per unit η) which is larger than the HERWIG prediction and much less than the PYTHIA default prediction.



Tuned PYTHIA (Set A) LHC Predictions

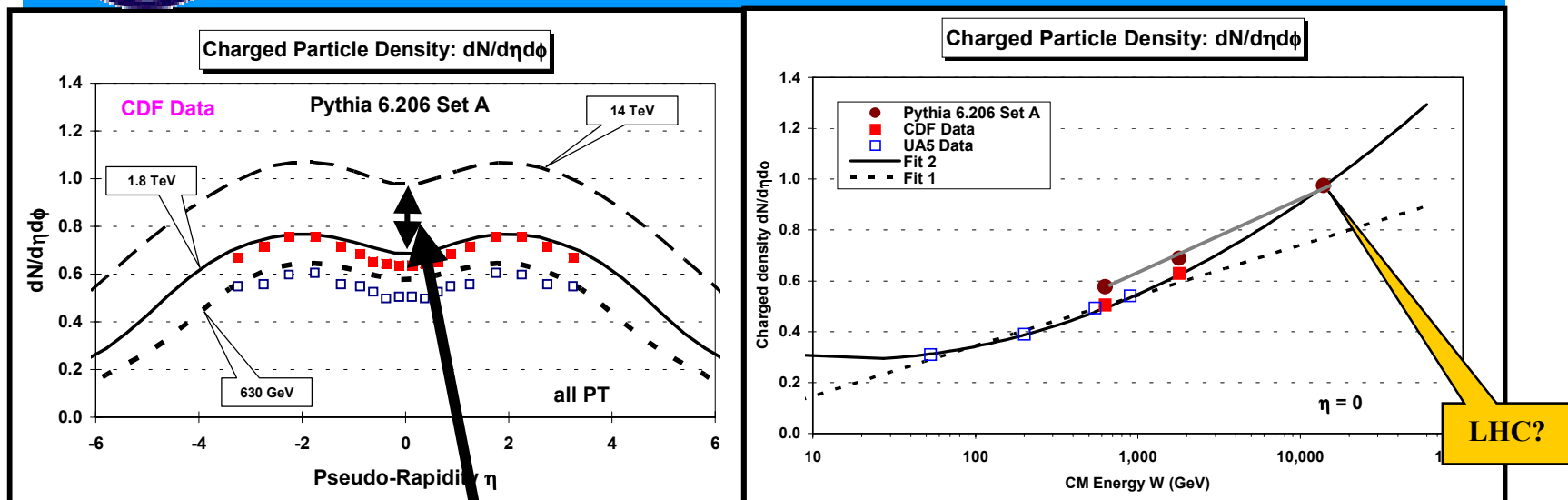
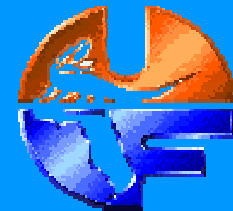


- ➔ Shows the average “transverse” charge particle and PT_{sum} density ($|\eta| < 1$, $P_T > 0$) versus $P_T(\text{charged jet\#1})$ predicted by HERWIG 6.4 ($P_T(\text{hard}) > 3$ GeV/c, CTEQ5L), and a **tuned** versions of **PYTHIA 6.206** ($P_T(\text{hard}) > 0$, CTEQ5L, **Set A**) at 1.8 TeV and 14 TeV. Also shown is the 14 TeV prediction of PYTHIA 6.206 with the default value $\epsilon = 0.16$.
- ➔ Tuned PYTHIA (**Set A**) predicts roughly **2.5 GeV/c per unit η - ϕ** ($P_T > 0$) from charged particles in the “transverse” region for **$P_T(\text{chgjet\#1}) = 100$ GeV/c**. **Note, however, that the “transverse” charged PT_{sum} density increases as $P_T(\text{chgjet\#1})$ increases.**

3.8 GeV/c (charged)
in cone of
radius $R=0.7$
at 14 TeV



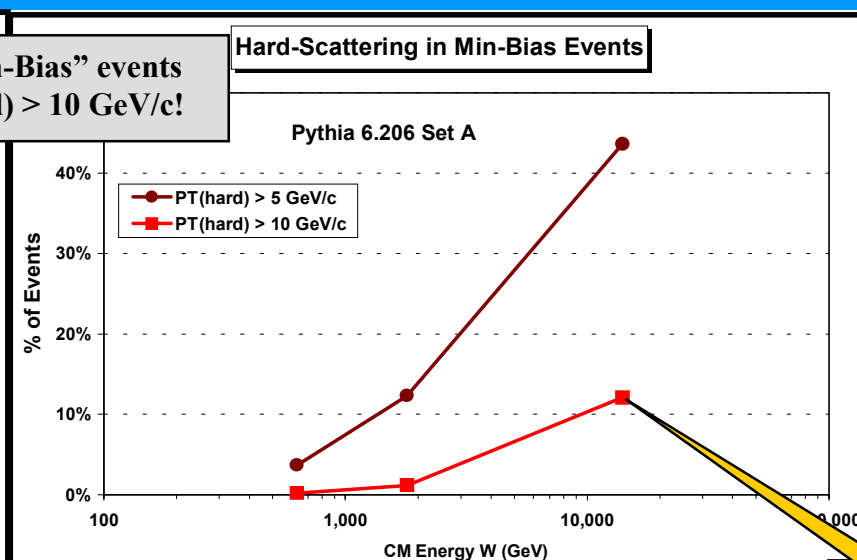
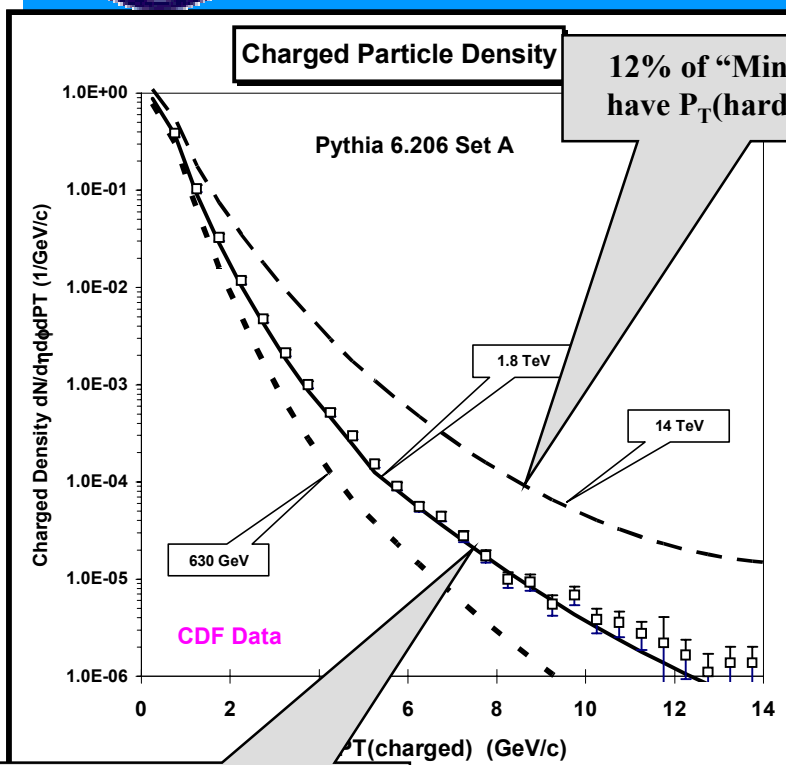
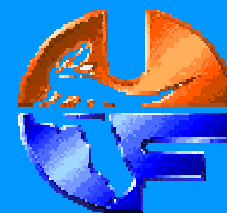
Tuned PYTHIA (Set A) LHC Predictions



- ➔ Shows the center-of-mass energy dependence of the charged particle density, $dN_{\text{chg}}/d\eta d\phi$, for “Min-Bias” collisions compared with the a tuned version of PYTHIA 6.206 (**Set A**) with $P_T(\text{hard}) > 0$.
- ➔ PYTHIA was tuned to fit the “underlying event” in hard-scattering processes at 1.8 TeV and 630 GeV.
- ➔ PYTHIA (**Set A**) predicts a 42% rise in $dN_{\text{chg}}/d\eta d\phi$ at $\eta = 0$ in going from the Tevatron (1.8 TeV) to the LHC (14 TeV).



Tuned PYTHIA (Set A) LHC Predictions



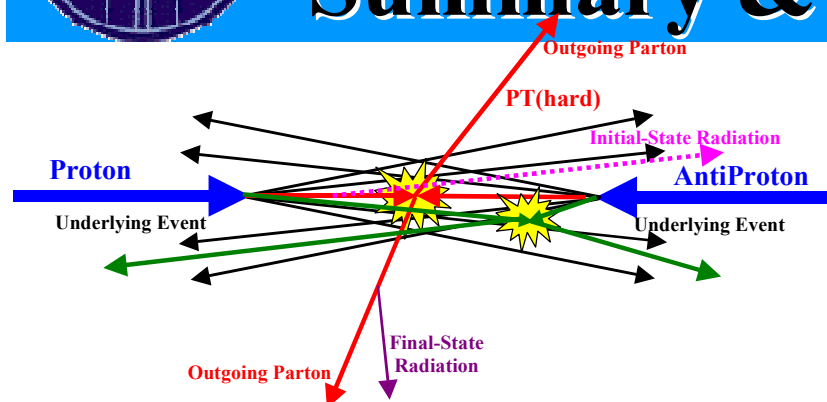
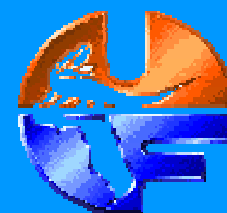
LHC?

➔ Shows the center-of-mass energy dependence of the charged particle density, $dN_{\text{chg}}/d\eta d\phi dP_T$, for "Min-Bias" collisions compared with the a tuned version of PYTHIA 6.206 (**Set A**) with $P_T(\text{hard}) > 0$.

➔ This PYTHIA fit predicts that 1% of all "Min-Bias" events at 1.8 TeV are a result of a hard 2-to-2 parton-parton scattering with $P_T(\text{hard}) > 10$ GeV/c which increases to **12% at 14 TeV!**



The “Underlying Event” Summary & Conclusions

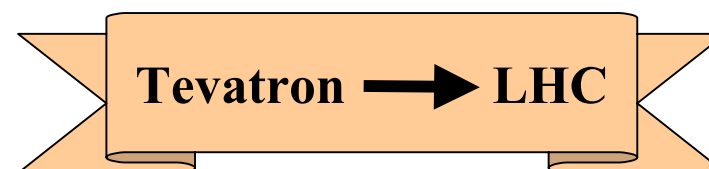
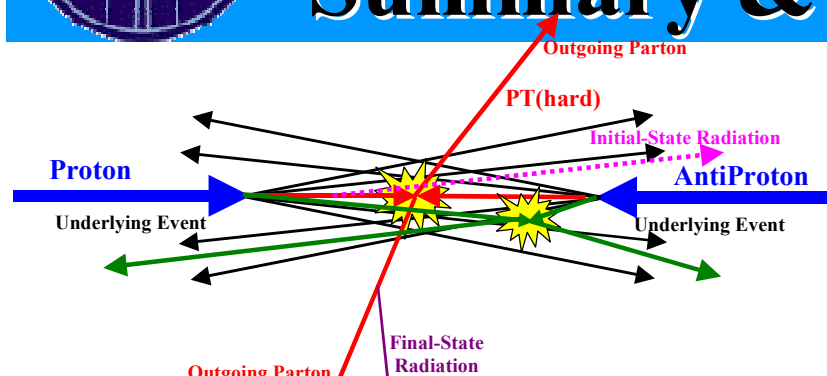
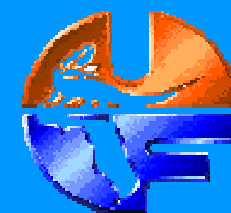


The “Underlying Event”

- ➡ There is excellent agreement between the Run 1 and the Run 2. The “underlying event” is the same in Run 2 as in Run 1 but now we can study the evolution out to much higher energies!
- ➡ PYTHIA Tune A does a good job of describing the “underlying event” in the Run 2 data as defined by “charged particle jets” and as defined by “calorimeter jets”. HERWIG Run 2 comparisons will be coming soon!
- ➡ Lots more CDF Run 2 data to come including MAX/MIN “transverse” and MAX/MIN “cones”.



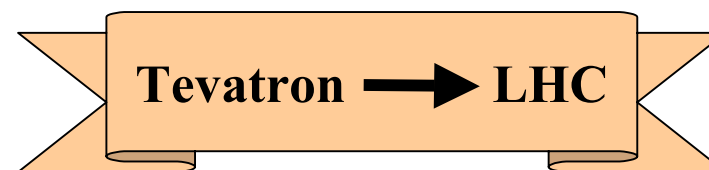
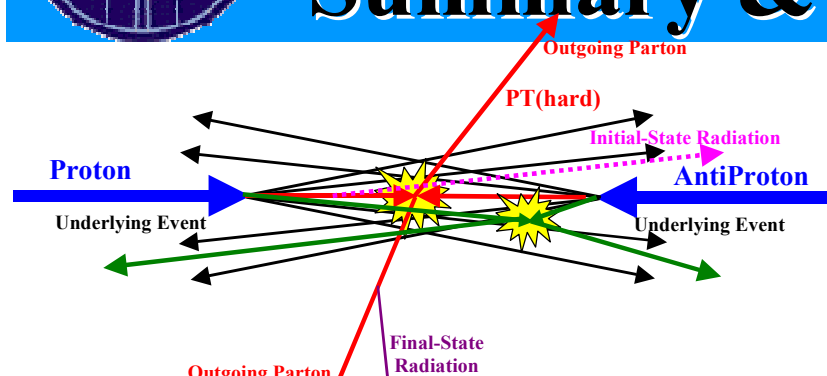
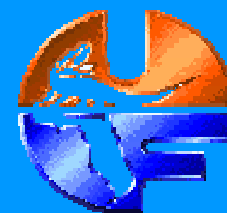
LHC Predictions Summary & Conclusions



- ➔ Both HERWIG and the tuned PYTHIA (**Set A**) predict a 40-45% rise in $dN_{\text{chg}}/d\eta d\phi$ at $\eta = 0$ in going from the Tevatron (1.8 TeV) to the LHC (14 TeV). **4 charged particles per unit η at the Tevatron becomes 6 per unit η at the LHC.**
- ➔ The tuned PYTHIA (**Set A**) predicts that 1% of all “Min-Bias” events at the Tevatron (1.8 TeV) are the result of a hard 2-to-2 parton-parton scattering with **$P_T(\text{hard}) > 10$ GeV/c** which increases to **12% at LHC** (14 TeV)!
- ➔ For the “underlying event” in hard scattering processes the predictions of HERWIG and the tuned PYTHIA (**Set A**) differ greatly (factor of 2!). HERWIG predicts a smaller increase in the activity of the “underlying event” in going from the Tevatron to the LHC.
- ➔ The tuned PYTHIA (**Set A**) predicts about a **factor of two increase** at the LHC in the charged PT_{sum} density of the “underlying event” at the same $P_T(\text{jet\#1})$ (the “transverse” charged PT_{sum} density increases rapidly as $P_T(\text{jet\#1})$ increases).



LHC Predictions Summary & Conclusions



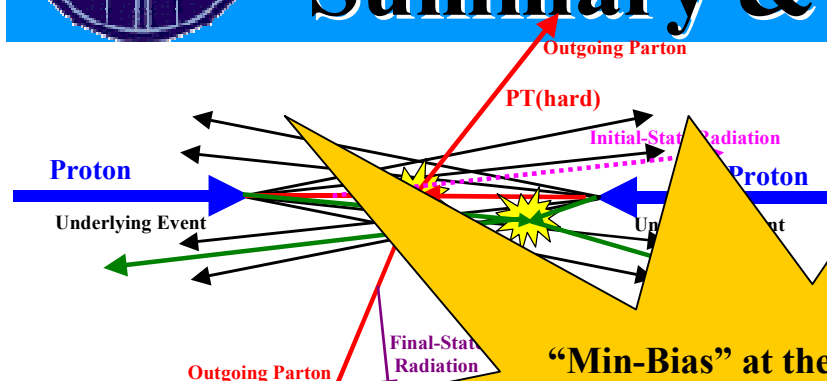
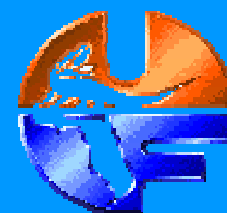
- ➔ Both HERWIG and the tuned PYTHIA (**Set A**) predict a 40-45% increase in the charged PT_{sum} density of the “underlying event” in going from the Tevatron (1.8 TeV) to the LHC (14 TeV). **4 per unit η at the Tevatron becomes 6 per unit η at the LHC.**
- ➔ The tuned PYTHIA (**Set A**) predicts that 1% of all “Min-Bias” events at the Tevatron (1.8 TeV) are the result of a hard 2-to-2 parton-parton scattering with $P_T(1^{st} \text{ jet}) > 10 \text{ GeV}/c$ which increases to **12% at LHC (14 TeV)!**
- ➔ For the “underlying event” in hard scattering processes the predictions of HERWIG and the tuned PYTHIA (**Set A**) differ greatly (factor of 2!). HERWIG predicts a smaller increase in the activity of the “underlying event” in going from the Tevatron to the LHC.
- ➔ The tuned PYTHIA (**Set A**) predicts about a **factor of two increase** at the LHC in the charged PT_{sum} density of the “underlying event” at the same $P_T(\text{jet\#1})$ (the “transverse” charged PT_{sum} density increases rapidly as $P_T(\text{jet\#1})$ increases).

12 times more likely to find a 10 GeV “jet” in “Min-Bias” at the LHC!

Twice as much activity in the “underlying event” at the LHC!



LHC Predictions Summary & Conclusions



Tevatron → LHC

- ➔ Both HERWIG and PYTHIA (Set A) predict a factor of 2 increase in the activity of the “underlying event” in going from the Tevatron to the LHC.
- ➔ The tuned PYTHIA (Set B) predicts a factor of 1.8 increase in the activity of the “underlying event” in going from the Tevatron to the LHC.
- ➔ For the “underlying event” the tuned PYTHIA (Set A) predicts a factor of 2 increase in the activity of the “underlying event” in going from the Tevatron to the LHC.
- ➔ The tuned PYTHIA (Set A) predicts about a factor of two increase at the LHC in the charged PT_{sum} density of the “underlying event” at the same $P_T(\text{jet}\#1)$ (the “transverse” charged PT_{sum} density increases rapidly as $P_T(\text{jet}\#1)$ increases).

“Min-Bias” at the LHC contains much more hard collisions than at the Tevatron! At the Tevatron the “underlying event” is a factor of 2 more active than “Tevatron Min-Bias”. At the LHC the “underlying event” will be at least a factor of 2 more active than “LHC Min-Bias”!

12 times more likely to find a 10 GeV jet in “Min-Bias” at the LHC!

Twice as much activity in the “underlying event” at the LHC!